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IMPROVEMENT OF GRAY'S HARBOR, WASH.

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READ SEPTEMBER 19TH, 1894.

WITH DISCUSSION.

An examination of the harbors of the United States on the Pacific coast will demonstrate that, in order to make them available for craft drawing over 15 ft., improvements must be made by the general Government. Harbors of refuge are much needed, inasmuch as the prevailing storms in winter cause the shore to be a lee, which circumstance, with the course of the great Japan current, causes loss of vessels and life.

The general Government has had an investigation made, and estimates for a harbor of refuge at Port Orford in Oregon, but nothing further has been done as far as the writer is aware. Appropriations have been made and improvements are being carried out for harbors, or rather, harbor entrances, at Yaquina Bay, the Coquille River entrance, the Siuslaw and Coos Bay, all in Oregon and south of the Columbia River, but no attention has been hitherto paid to any place north of that river.

There are two fair entrances north of the Columbia River, both of which gives the best natural entrance on the coast, north of San Francisco; these are Shoalwater Bay or Willapah Harbor and Gray's Harbor. It is the purpose of this paper to direct attention to the latter alone.

The United States Coast and Geodetic Survey, in the fall of 1891, made a survey of the bar at the entrance to Gray's Harbor, which shows in the line of deepest water a minimum depth of 16 ft.

The crest of the bar at that depth is less than ¼ mile in width, and the distance between the outer and inner 18-ft. curves is about ½ mile; the bar is 3 miles from the gorge of the entrance formed by the two points, Point Brown or Damon's on the north and Chehalis or Peterson's on the south; the distance between these points at low water is about ¾ mile; at high water, 2 miles; at low water the minimum depth at this gorge is 48 ft.; the maximum, 81 ft. These points are the resultants of several natural forces, which are the Japanese current, the prevailing northwestern or southwestern storm winds and the fluvial discharge.

The channel of deepest water over the bar has a tendency to vibrate over a certain distance, but a close examination of the entire crest will show that, although the discharge from the harbor expands and covers a distance of over 3 miles in width, the difference in depth from the line of deepest water is only a few feet less, which assures that, if the water be properly concentrated by jetties, a depth sufficient for any sea-going craft can be obtained.

The Pacific Ocean breaks at the 10-fathom curve, and this curve is closest to the shore opposite to the entrance to Gray's Harbor; therefore, the combers will have less extent, and last January demonstrated the fact that vessels can safely enter at all times, and the depth of water is the only limiting force.

The harbor is somewhat of a heart shape, with the top toward the west. North and south, it is in its greatest width about 12 miles, and east and west about 15; at low water, several channels are developed, with an extent of sand and mud banks separating them.

Besides the Chehalis River, the main stream, there are the Humptulips, the Hoquiam, the Wiskah, the Newskah, the John's and the Elk Rivers, beside numerous creeks discharging into the harbor, the water-shed covering about 3 500 square miles with a rainfall of 90 ins.

There are two well-defined channels extending from the mouth of the Chehalis River to the gorge; these are connected by two cross channels.

The main channels are locally distinguished by the names north, south and middle.

At the east end of the harbor is situated the town of Hoquiam, where are large lumbering interests and immediately adjoining, but on the Chehalis River before it enters the harbor, is the city of Aberdeen, also with a number of large saw and shingle mills, and adjoining this city is the town of Cosmopolis, with the fine lumbering establishment of the Gray's Harbor Commercial Company and several shingle plants.

The annual output of these establishments amounts to, when running at their full capacity, 171 000 000 ft. B. M., and 213 000 000 shingles.*

There are also canneries and other establishments.

The only other town of any consequence on the harbor is Ocosta, situated on South Bay. It has two saw-mills, a tub and pail factory, a brewery, ice plant, flour mill, sash and blind and several shingle factories. It is also one of the termini of the Northern Pacific Railroad, and the nearest one to the ocean being only 3 miles from the entrance between the points.

Several years ago, a survey of the Chehalis River and Gray's Harbor, with a view to its improvement, was ordered by Congress. This was made and a project approved, for laying out an appropriation of $50 000, which sum was expended in the removal of the shoal at Cow Point, between Aberdeen and Hoquiam. Twenty-two ins. in depth was gained over a limited area by this outlay, but at the expense of the lower shoal near the long wharf.

The best authorities hold that improvements to streams should be begun at the lower part, as it is sure then that the benefit is felt of all finished work as you proceed, and this is proved in this case, for the silt and sand from Cow Point shoal was deposited in the expanded channel and added to the shoal caused by the meeting of the waters of the Chehalis and Hoquiam rivers with those of the middle channel.

The work of improvement consists of a system of pile jetties, commencing at the south bank of the Chehalis, and extending by angular

* Report of the Chief of Engineers, U. S. Army.

courses across the south channel, leaving a space of 1 000 ft., mattressed so as to give a depth of 8 ft., with a jetty dam of the same construction across the middle channel.

If the lower shoal had been taken care of at first, the writer believes the results would have been much more satisfactory. He also thinks that where water is to be trained, it is of much benefit to use curves, as water will follow such an alignment, but is sure to cause an eddy where angles are used.

With proper calculations and a curved trace, enough water could have been deflected from the river by a jetty unconnected with the south bank to perform all the scour needed, and this curved trace, with the concave face to the north, would have had a tendency to make the deep channel along the jetty, and not as it does at present, deflect the current toward the embouchure of the Hoquiam River, thus tending to form a bar below it.

These jetties are formed of piling driven 6 ft. apart in two rows, with mattresses of brush sunk and filled in with fascines weighted with stone and sand bags.

The writer is confident that this construction is unnecessarily expensive, as, there being no teredo, a system of piles and sheet piling would answer every purpose, and it would certainly happen that the jetties would fill up with sand in the inside.

From the mouth of the John's River at Markham, north to Ned's Rock, there is a neutral line east of which is a deposit, principally silt. West of this line sand preponderates; this line would seem to be the limit in the main for the silt of the river, and the sand brought in by the flood tide.

Below the mouth of the Wiskah at Aberdeen, the Chehalis River has a width of 1 100 ft. Its mean hydraulic depth is 15.76 ft. at low water. Just below, however, near Cow Point, the river expands to 2 300 ft., with a mean hydraulic depth of 10.18 ft. also at low water. The most natural course for improvement in direction is the south channel. This gives the shortest distance to the ocean, is nearly direct and curved so as to give the nearest channel to the shore, requiring wharfs of moderate length to get to deep water; but the commercial interests of Hoquiam as regarded by those controlling them demand the improvement of the north.

The training of the channel should be done with care. It cannot be

done except at the expense of the tidal area; but if given a proper alignment and direction, as well as a right proportion in width, the volume of water is ample to preserve the requisite depth.

The width should be enlarged as it approaches the neutral line, and in the opinion of the writer should not be carried any further.

The river mouths ought to be trained so as to flow into the main channel parallel to the main stream. The Hoquiam, before the improvement, had such an embouchure, and the two rivers maintained separate channels, the Hoquiam to the north of the lower shoal and the Chehalis to the south of it. The Chehalis, now diverted by the improvement, is filling up. This is proved by the grounding of the United States Coast and Geodetic Survey steamer *McArthur*, and a few days after of the steamer *Point Loma*. Lieutenant Crosby, who is in command, states that the tide was, if anything, over the half when he grounded, and the charts show that there was formerly plenty of water at that state of the tide to float a vessel with greater draft than the *McArthur*.

While the training of the river through the harbor is commercially of the greatest importance, the writer considers the matter of a harbor of refuge of still more consequence. During the last few seasons several large steel vessels, waiting for an opportunity to enter the Columbia River, have been wrecked, with great loss of life, north of the entrance to Gray's Harbor. The last two were the *Abercorn*, laden with railroad iron, and the *Ferndale*, with Scotch coal.

North and south bays give a large area of anchorage and good shelter from all storm winds, and the depth of water at the gorge would give assurance of as deep water on the crest of the bar if proportioned in the same manner. The rise of tide on the bar, according to the notes of the United States Coast and Geodetic Survey, is for the mean of the greater high waters, 9.38 ft., and for mean of the lesser, 7.71 ft. This gives 25.38 ft. and 23.71 ft. as the greater and lesser depths at high water on the bar.

In the harbor this height is increased, as is usual under such circumstances; extreme rise of tide at Aberdeen approaches 13 ft.

It is a difficult matter to procure good stone on the harbor, and the writer is certain that a construction as described for the training of the river, properly modified, would be successful, as the volume of fresh water coming to the bar is so great that frequently quite fresh water

can be dipped up and it is never more than brackish in the main channel, so the destructive teredo is no where to be found, and fascine filling, loaded with sand, would be likely to answer all purposes.

The depth of water at the gorge at low water would also indicate that half-tide jetties would supply all the concentration of force necessary to give a depth sufficient for vessels of the greatest draft, and thus the tidal area would be made available to the fullest extent by the free admission of the flood tide.

The neutral line mentioned, where the sand meets the silt of the river, indicates a deposit of sand brought in by the flood tide, but there is also another cause for this deposit, viz., the prevailing storm winds from the northwest and southwest. This traveling of the sand can be both seen and felt, but can be easily remedied by the cultivation of the *Arundo Arenarea.*

While accretion and abrasion has been going on about the north point, the alterations in the south are scarcely perceptible; in fact, the shore has not materially changed in 11 years.

To conclude, the rules to govern in the main and to be carefully considered are: To give the river a uniform depth by regulating the alignment, flow and width, using formulas found to give satisfactory results by the experience of others, and recognizing the fact that to obtain this the current must be as equable as possible and the channel as straight in direction.

The ebb tide is the most efficient agent to deepen the channel over the bar; therefore, it follows that the admission of the flood must be as unrestricted as possible. Converging jetties, as so successfully used at Dublin and other places, must be used.

Dredging may be advantageous in some places, as thus the silt may be got rid of without a deposit again in some other part of the channel, and, by pumping, the land reclaimed may be sooner rendered available and of considerable value.

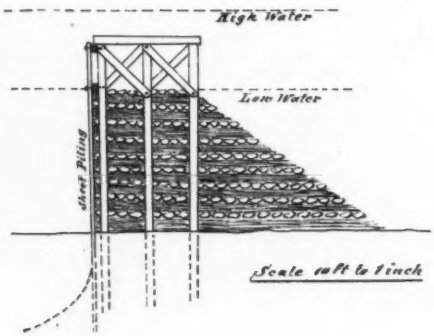
The extreme narrowness of the crest of this bar is occasioned probably by the Japan current causing erosion on the ocean side, and if the jetties be carried to a little beyond, there will be no farther extension of the bar seaward. This current is so pronounced here that vessels entering have to take into consideration a considerable drift to the south.

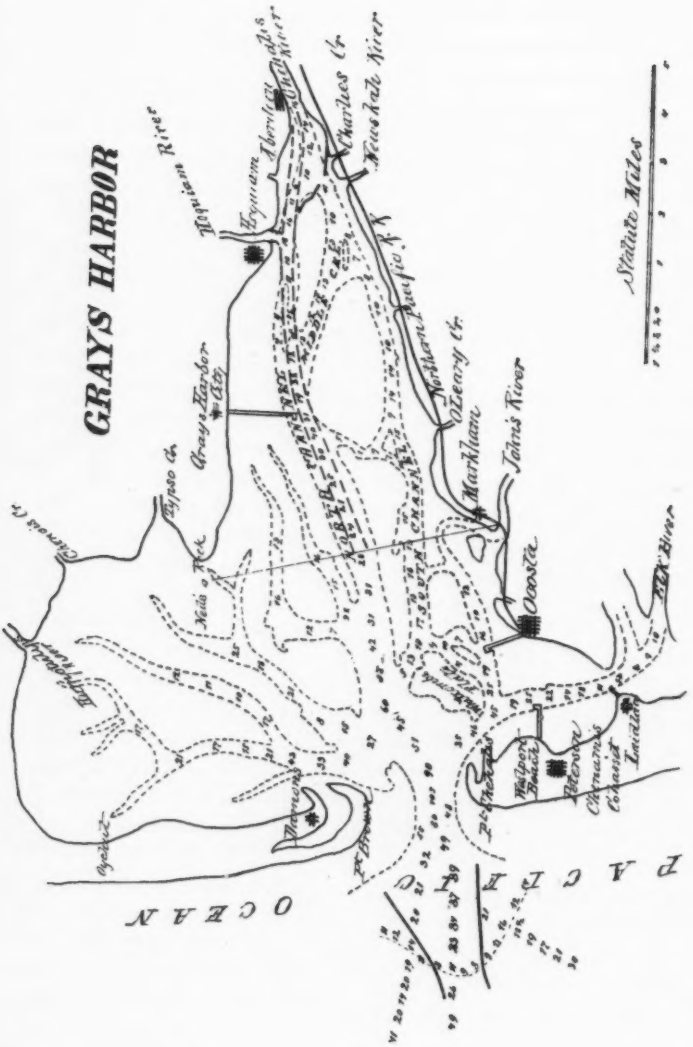
Vessels drawing 17 ft. of water frequently pass out, and the re-

sources of the country in timber and other productions are being developed so fast that, besides the demand as a harbor of refuge, that for improvement for the benefit of commerce is coming on amain and cannot be long neglected.

The ocean greyhounds as used on the Atlantic are scarce introduced on the Pacific, but the tendency is at all times to encourage fast mail delivery, and at this harbor the rail meets the ocean and a whole day can be saved over any other route. The main reward, however, to be obtained is a perfect harbor of refuge, and the saving of fine vessels and valuable lives.

Facts are stubborn things and are incontrovertible in argument; therefore, to prove that this is the best location for a harbor of refuge on this coast, it is only necessary to state the following, viz., last January was a very stormy month, so much so that the two lighthouse tenders *Manzanita* and *Columbine* were bar bound for 23 days in that month at Astoria, inside the mouth of the Columbia River, with a flag of distress flying from the Tillamook lighthouse, and could not get out, and during that time there were only five days that vessels did not pass in or out over the Gray's Harbor bar, and Lieutenant Crosby has told me that he passed in during a severe gale and did not ship one drop of water.




GRAYS HARBOR
Hoquiam River
Hoquiam
Aberdeen
Wishkah River
Chehalis R.
Charles Ck.
Wishkah River
Statute Miles
Grays Harbor City
Grays Harbor
Espoo Ck.
Northam
Point
Markham
Cleary Ck.
John's River
Chehalis R.
Point
Oceola
Bay
Willapa Harbor
Ocean
Entrance
Entrance
Entrance
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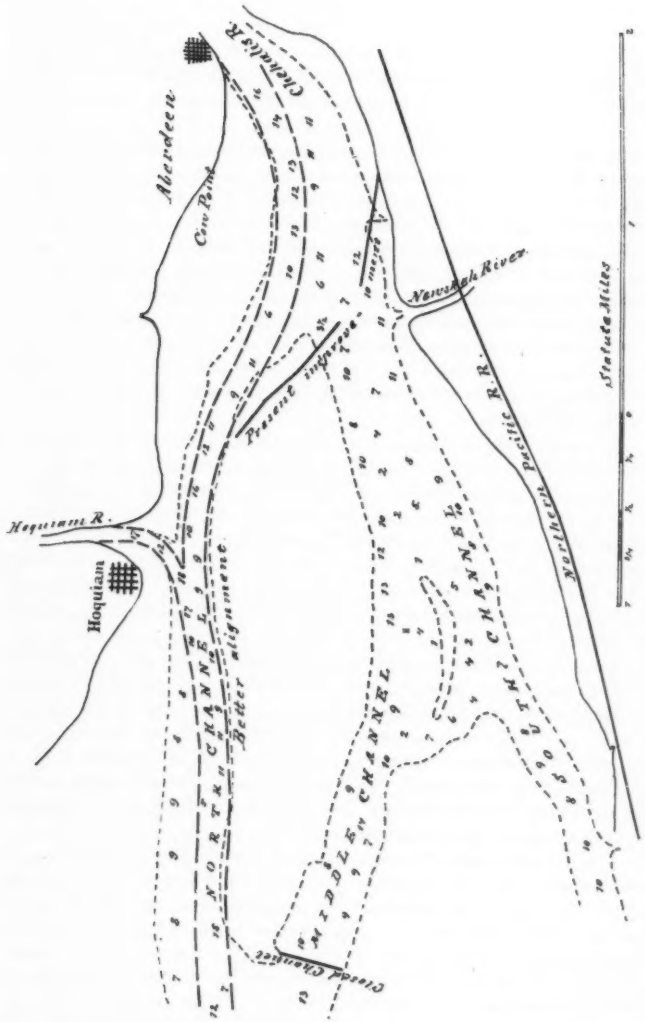
PACIFIC


Chehalis R.
Aberdeen
Cow Point
Present improved
Newaukah River
Northern Pacific R.R.
Statute Miles
Hoquiam R.
Hoquiam
Better alignment
NORTH CHANNEL
MIDDLE CHANNEL
SOUTH CHANNEL
Coastal Channel

CORRESPONDENCE.

THOMAS W. SYMONS,* M. Am. Soc. C. E., states that the author's plan for the improvement of the entrance to Gray's Harbor is, as far as the construction goes, probably the boldest and most remarkable that ever emanated from an engineer.

To build two jetties about 3 miles in length right out into the Pacific Ocean, in one of its stormiest portions, on and amid drifting sands, and to construct these jetties of brush and sheet piling driven presumably from a tramway or platform built to a level of mean tide (see cross-section) is certainly a remarkable proposition. Such a proposed construction is entirely inadequate and absolutely impracticable. It would be impossible to build it; but if one could conceive that it could be completed, the first storm would utterly wreck it in an hour.

He is curious to know how the author would build his jetties from his platform submerged at half tide, and which, even in the quietest weather and lowest tide, would be always swept by the waves and swells of the ocean.

In far less-exposed situations, and with a substantial platform or tramway 20 ft. above the water, oftentimes great difficulty is found in constructing and sinking brush mattresses to place. To attempt to control the ocean waves and currents by sheet piling backed by a brush pile is certainly most chimerical. The fact stated in the paper that the waves here often break at a depth of 10 fathoms is sufficient proof to one familiar with the subject that something more substantial than brush and sheet piling must be used to withstand their gigantic power.

As shown on the map accompanying this paper, the depth in the harbor throat is 80, 90 and 105 ft. The author's proposed jetties converge at the bar to a width about equal to the width between low-water lines at the harbor throat. The sands of the bar are easily eroded. The channel between the jetties so confined would be approximately as deep as in the harbor throat. Under these circumstances what would naturally be expected to become of the jetties located as shown, or one of them at least?

The littoral ocean current in front of Gray's Harbor moves to the north and not to the south, as stated by the author. This is proven by the fact that buoys going adrift, wreckage, etc., are almost always carried to the north by the northerly current, which is so well recognized that it is known as the Davidson inshore eddy current, named for Prof. Davidson, the distinguished and able Chief of the United States Coast Survey on the Pacific coast. This current is, however, too slight to have any appreciable effect on the bars or sands along this portion of the coast.

* Capt. Corps of Engrs., U. S. A.

The great southerly Japanese gulf stream, to which the author attributes the narrowness of the Gray's Harbor bar, is felt only at a distance of about 50 miles from shore.

In the inner harbor the construction of the training and controlling dikes is very simple, a double row of piles about 4 ft. apart, filled in with brush fascines weighted with stone, all tied together with wales and cross ties, and all underlaid with a brush mattress.

The author chara terizes this construction as unnecessarily expensive and strong. This view is not shared by many practical men on Gray's Harbor, who have expressed surprise that it has stood at all, considering the elemental forces arrayed against it. Some years ago a pile and sheet pile structure, like that advocated by the author, was built in a similar, but less exposed, situation in Tillamook Bay. It was built as substantially as such a structure could be built, but during its first winter it was nearly all carried away. To the mind of the writer it is certain that such would be its fate at Gray's Harbor.

The plan of the work was carefully considered and adapted to existing conditions and demands. The advantages of a curved trace of great radius over a trace of straight lines, connected with slight deviation angles, is more theoretical than practical. The middle channel dike has not yet been entirely completed, and its effect to accomplish the purpose aimed at ascertained.

Notwithstanding the author's adverse criticism of the effects of the works, the writer makes the assertion that as far as completed, they have been eminently successful and give the liveliest satisfaction to the people and interests which they are intended to benefit.

It necessarily takes time for such works to perform their functions and establish a new and better order of things. In the re-adjustment of affairs, it is inevitable that with the deepening of the channel in in some places, there is shoaling in other places, which must account for the grounding of the *McArthur* mentioned.

The author is, in common with many others, impressed with the harbor of refuge idea. In the writer's opinion the question of harbors of refuge along this coast is very little understood; their importance and value is greatly over-rated, and an immense deal of clap-trap talk is indulged in about them. The existence of wrecks along the coast, like the *Abercorn* and *Feradale*, mentioned in the paper, are pointed out to emphasize and illustrate the necessity of harbors of refuge. The facts are, that these wrecks are almost invariably caused by the vessels getting out of their courses and reckonings in thick weather, mistaking lights or getting disabled and beyond control, and going blindly upon the shore. It is almost, if not quite, impossible to point out an instance of a wreck which has occurred on this Northern Pacific coast in many years which would have been averted by a harbor of

refuge, unless perchance the latter should have been in the direct path which the vessel was blindly or helplessly pursuing.

Under the conditions prevailing along the coast, the best course for a vessel to pursue in the event of a storm or partial disablement is to keep at a safe distance from shore. With the sea running high an attempt to enter a bar harbor such as Gray's Harbor must ever be a dangerous undertaking.

If the entrance to Gray's Harbor is ever improved by the General Government, it must be justified from a commercial standpoint and not from the standpoint of a harbor of refuge.

The opening statement of the paper will cause surprise to those familiar with the natural capacities of the entrance to San Diego Harbor, San Francisco Harbor, and the Columbia River, as will also his statement further on, that the entrance to Willapah and Gray's harbors are the best natural entrances north of San Francisco; better even than the Columbia River entrance. The water-shed of Gray's Harbor is about 2 150 square miles, not 3 500 square miles as stated.

Hon. GEORGE H. EMERSON writes that he has no doubt that the system of inside improvement suggested in the paper, that of training both sides of the channel, would prove absolutely effective and give a channel of approximately the same width, and approximately the same depth, as at Cosmopolis, or about 30 ft.; the expense, however, attached to such improvement would be very considerable. It seems to him entirely possible that the plan already adopted will accomplish a result adequate to all purposes when complete, if in the coming season the dyke across the middle channel be extended by means of sheet piling 2 000 ft. east from the north end, and 1 000 ft. west from the south end. Tugboats now claim a decided improvement in the channel below Hoquiam, and a marked improvement at Cow Point. They have a tide gauge by which to leave the dock at Hoquiam, and any deviation from their figures, by way of less water, would subject them to detention that would very soon necessitate the correction of their gauge.

Referring to the outer bar he agrees with the author in the statement that, from the crest of the bar to a 10-fathom sounding, the distance is less than at any bar on the coast, and also agrees that the closing of the Chinook channel and the extension of a jetty from Point Damon in a southwesterly direction would probably effectually deepen the crest of the bar. Also, that when once deepened it would be a permanent improvement, and not simply a process of sending the bar seaward, as is so often the case; but he is not of the opinion that sheet piling would stand for such jetty, although he would be inclined to try the experiment, as it might be that sand would form about the piling before heavy storms and the teredo succeed in sweeping them out, but thinks there is no great difficulty in the construction of a jetty

from Point Damon, and that the rock on the Hoquiam River would be of sufficient solidity to resist action of the sea until such time as the sand came to its assistance.

The writer says further, that the survey that is now being made on the bar is with reference to its improvement, and that after having seen the figures resulting from this survey and comparing them with the surveys of previous date, he thinks that, perhaps, much more definite plans may be made as to the course that should be pursued to properly train the waters that pass in and out of the harbor entrance. He agrees with the author that with proper improvement of the entrance of this bay, this will become the most accessible harbor on the coast, and will, perhaps, solve the problem, so long before the United States, of providing a first-class harbor for refuge.

Mr. C. F. White writes that he has carefully read the paper and agrees with the author as to the improvement of this harbor in every particular.

He notes, especially, the reference as to deepening the channel and the system of piles and sheet piling, and endorses the idea in every particular. The absence of teredo in this harbor makes the sheet piling practicable where it would not be if the conditions were the same as to the teredo here as they are in Puget Sound and other places.

Hon. F. G. Deckebach says that he is heartily in sympathy with any plan that leads to the improving of the outer bar; the *modus operandi* he leaves to those skilled by education and experience to deal with such questions.

Concerning the necessity of such improvements as stated in the paper, he says, without hesitancy, that it is imperative, both for the safety of life and property, as well as the demands of the increasing commerce of Gray's Harbor.

The idea of making this harbor a harbor of refuge was first forcibly impressed on his mind by the late Lieutenant Crosby, of the United States Navy.

Before he came to an untimely end in the breakers north of the harbor, he had been engaged in the hydrographic work of the United States Coast Survey between Gray's Harbor and Cape Flattery during five months and had crossed the bar many times and in many directions, and he was very enthusiastic when talking of its improvement, especially for a harbor of refuge; he also considered that one jetty would be sufficient—that to the south.

From this harbor, north, for a distance of over 100 miles, the coast is practically unbroken. No shelter is to be found for any vessel throughout this entire distance.

Nearly all of the vessels wrecked to this north of this harbor were destined for the Columbia River, but from the stormy weather prevail-

ing, they preferred the danger of a lee shore to the almost certain destruction of crossing its bar.

Gray's Harbor bar is considered by ship captains the easiest one to cross on the coast, it being, as they state, only ½ mile across, while that of the Columbia River is about 6 miles.

Congress has made an appropriation for a first-class light to be at once erected on the south point of the entrance.

With an average depth of 16 ft. on this bar there has never been but one instance where an accident occurred in its passage, and this was caused by the carelessness of the captain.

After the entry there is excellent anchoring ground. At the present about 300 vessels pass in and out in 12 months, and with a lighthouse and bar improved, so as to allow the entrance of ships of any size, the danger of wreck will be very much reduced, if not entirely done away with; where they have been frequent to the north of the entrance.

The prevailing current along the coast is from the north to the south. This the writer knows to be a fact, from many proofs, which, during a six years' residence, have demonstrated it.

Common humanity demands that this be made a harbor of refuge, with sailing directions, so that a vessel can enter at all times if it be within the bounds of possibility to do so.

B. W. DeCourcy, M. Am. Soc. C. E., writes in answer to Captain Symons' discussion, that early in the nineteenth century, one of the most eminent engineers in England made a statement that it was quite impossible to build a ship large enough to carry coal sufficient for steaming across the Atlantic Ocean. Afterwards Lord Stanley in the House of Commons declared he would agree to eat up the first steam vessel to make the passage. The truth of the last incident, however, he does not vouch for.

The assertion of the engineer, however, and the commencement of regular steam navigation with the *Sirius*, *Great Western*, *Liverpool*, and other steamships warned engineers to be guarded in their statements, and the word "impossible" has been eliminated from their vocabulary.

The author's suggestion of the sheet piling does not enter into details, but, in referring to the bar while talking of the inner improvement, he uses the words "properly modified."

If the improvement be necessary and it be impossible to obtain rock that will answer, the author does not think the profession of the present day will give up and say that no other plan but the old will suffice. In the inner improvement, he is confident that in the training of the river channel the plan of work suggested could be build sufficiently strong to answer all purposes, and such a plan would cost much less than the plan as built.

The author has had a residence of three years on this harbor, and

has been watching it carefully, and can show single piles that have stood for years and are now standing in the most exposed positions on the harbor, and right where the sea has the greatest fetch, being used for guide piles to the channels.

He is satisfied that if Captain Symons could spend a month or two on the harbor, he would agree with the author in some particulars.

The severest storm occurring here is the southwest; this would aid in the accumulation of sand in the rear of the south jetty, which single work may be as Lt. Crosby considered all that is necessary.

In regard to the ocean currents.

First.—The position of the "line of deepest water" (so called on the original United States Coast and Geodetic Survey chart), the Chinook channel forming an angle to the southwest after it gets outside the harbor entrance, being the resultant of the two forces, the current from the north and the ebb tide and discharge of the rivers both combined.

Second.—The British ship *Ferndale*, loaded with coal, was cast ashore about 10 miles north of the harbor entrance. Her cargo did not scatter to the north, but to the south, and was found all the way along the beach, nearly to North Cove.

A number of others, as well as the author, have seen a dead whale drift away to the south and finally strand near the entrance to Willapah Harbor, the day being perfectly calm, and any wind there was blowing from the south. Boats also getting adrift are invariably found to the south of the harbor mouth.

Third.—The lamented Lieut. Crosby told the author and others that he found the current to come from the north, and that he always had to make allowance for this in entering the harbor.

The author has seen two buoys come ashore that floated in from the north and one of them is to be found at present near the cottage of Col. F. D. Huestis on Chenamis Beach 3 miles south of the point.

The proposition of a harbor of refuge does not emanate from the author, but from those men themselves who "go down to the sea in ships."

The late Lieut. Crosby suggested this place as being the best he had seen along the coast for such a purpose, and, from his standpoint, much needed.

At a meeting at the city of Aberdeen concerning the improvement of the harbor and bar, when the subject of a harbor of refuge was mentioned, Captain Mitchell, an old master, was reported in the papers as follows:

"That he had crossed nearly all of the bars on the Atlantic and Pacific coasts, and with the exception of San Francisco, Gray's Harbor was the safest of all. At Humboldt and Coos bays, where the Government had spent hundreds of thousands of dollars, he had been bar-bound 24 days, while at Gray's Harbor he had never been detained over five

days, and then only when no vessel could have crossed any bar. This bar never shifted much, and he had always found from 18 to 30 ft. of water, and that it was in, his opinion, the best and easiest to improve he ever passed over, and, if improved as a harbor of refuge, would without doubt be the means of saving many valuable lives."

Lastly.—One of the survivors from the *Ferndale* stated that according to their departure, course and reckoning they ought to have had plenty of sea room, but they found themselves in the breakers before they were aware of being near them.

The current not being taken into account, they drifted into the breakers.

Sometimes it is impossible to keep off a lee shore and take that sea room spoken of by Captain Symons; a lee shore and a storm with a current setting along the shore are hard conditions for a sailing vessel and make a harbor of refuge desirable.

The uncontrovertable proof of the last paragraph of the paper referring to last stormy January shows the capabilities of the harbor. As to the water-shed of the Chehalis River, it is impossible to get a correct or rather exact measurement; the entire county, except a small amount drained by the North River and a narrow strip on the ocean, is in this water-shed, the area being 2 298 square miles, nearly the entire Lewis County. A part of Mason, a large area in Thurston and part of Pacific, are also components.

The author made a careful examination of the drainage, and is sure he is correct in stating that it has an area of very nearly 3 500 square miles.

With regard to alignment, a famous English engineer says: "All works," referring to training, "ought to be disposed parallel, or according to the direction of the stream, so that the water, instead of being stopped or thrown off, shall glide gently by, with the least interruption possible." * * * "On this account, all angles and sudden turns should be avoided and when a turn must be made, let it have as easy a sweep as possible," etc.

One thing is certain, that the facts are that the ebb tide rushes through the opening left for the south channel with such force that at times it is impossible or dangerous to attempt to row against it, and at this time it draws from some distance toward Hoquiam along the face of the jetty, and at others the deflection of the water from the face can be seen causing a peculiar riffle where it strikes the water of the Hoquiam River at its mouth.

The author's idea was to suggest a general plan, without determining details, for a successful improvement of the harbor.

It will be seen in his discussion that Captain C. F. White, the manager of the largest establishment on the harbor and a practical man, agrees with him.

AMERICAN SOCIETY OF CIVIL ENGINEERS.

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740.

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PLATEN PRESSES FOR LETTER-PRESS PRINTING, EMBOSSING, CUTTING AND SCORING.

By JOHN THOMSON, M. Am. Soc. C. E.

PROLOGUE.

Letter-press printing, the world over, is known as "The art preservative of arts"; and the compositors, the publishers, the editors and the press-makers may properly be proud of this far-famed legend, for each can safely entertain the belief that he forms an important integral part of the greater whole. Indeed, it is within the truth to say that the "art preservative" is to all modern arts a foster-mother; for it can neither rise nor fall, progress nor recede, without communicating or receiving similar action to or from the arts upon which it is builded. And it is expected that a somewhat similar analogy will be herein shown to exist in engineering.

There has been considerable hesitancy as to the propriety of presenting this paper, relating as it does to a special art and being entirely mechanical. And yet, notwithstanding that it may possibly be looked upon as an innovation upon established usage, there is no little satisfaction in the thought that the craftsmanship which gave life to

engineering is not only itself a preservative of arts but that it is in fact, as in legend, the originator thereof; for Solomon's guest of honor at the opening of his temple, and without whom to-day all arts would decay and crumble, was a master of the hammer, the file and the forge.

But, most seriously, the object the accomplishment of which is desired above all others, as a result of this presentation, is that this quite modest attack upon what has been termed our "unseen barrier" may induce similar action upon the part of others, thereby increasing the scope and usefulness of our Society and making its *Transactions* not only "preservative of arts," past, but as an advance publisher of the engineering progress of America.

Scope of the Paper.

The writer's connection and experience with the "art preservative" has been confined to one of the branches of the mechanical limb, that is, to the design of platen presses employed for general jobbing, fine catalogue and color printing, label and cutwork, book-cover inlaying, embossing, and the cutting and scoring of blanks for the manufacture of folding paper boxes.

It may be proper to state that nearly all of the important devices in the presses to be described are the subject of patent monopoly; but there is no patent, nor is there a protective tariff, upon the experiences which have been acquired, or the mistakes made, in reaching successful results. It is hoped, therefore, that discussion may be freely offered to bring out any feature which may be of interest or value to any one. Only a portion of the drawings, diagrams or illustrations here presented have before been publicly used, and these only in trade catalogues and a few journals entirely devoted to the interests of printers. Moreover, it is not intended to go much, if any, beyond the narration of the personal knowledge of the writer. To do more than this would make a book and involve a history of the art, for which he has neither time nor inclination.

A Few Preliminary Observations.—Principles Involved.

In the United States and Canada there are about 25 000 printing establishments. Assume that the average expenditure of these for machinery each year is but $600, and we have the snug sum of

$15 000 000 as the yearly expenditure for machinery alone, from which it may be inferred that the mechanical department of the printing industry is one of importance.

The duty required of printing presses is most varied and exacting. Probably in no other class of service is the performance demanded of machinery anything like so severe as in letter-press printing and paper embossing, a condition due to the inherent principles of operation, the frequent urgency of output and occasionally to unskilful attention.

Simple contact between types and paper will not print. Printing requires pressure, hard pressure, very hard pressure, and that, too, with extreme accuracy of movement under great strain.

Rigidity of structure is an essential in all printing machinery, but especially is this so in platen presses. In cylinder printing presses the actual surface in contact at any one instant is but a line the length of the cylinder; but in a platen machine the line becomes a plane surface equal in area, say, to 1 000 sq. ins. It is no contradiction in terms to say that a press may be strong and yet not rigid. A hard, unyielding, solid impression is regarded of importance second only to accuracy of operation.

There are some printers who yet believe, as did the earlier members of the craft generally, that long duration or "dwell" of the platen upon the types is advantageous; but this now is not usually accepted as a fact in practice, nor do we find for it a theoretical basis, to which a single illustration will suffice. Thus, in a platen press operating at, say, 1 200 impressions an hour, the actual hard impressional contact over the entire surface of the form will probably not "dwell" to exceed .08 or .10 second. In a cylinder press, however, working at the same speed, the actual contact instant, assuming the breadth of lines equal, say, to .02 in., would not exceed .002 second, or a period of time in the platen press of from 40 to 50 times greater duration than in the cylinder; and yet two such printed sheets might not be distinguishable one from the other. Consequently, it may be accepted as a fact that printing ink is in nowise absorbed by the paper, but is forcibly driven into its fiber.

In a cylinder press, if the face of the form exactly coincides with the pitch line of the rack of the bed; if the face of the sheet to be printed on the cylinder exactly coincides with the pitch line of the cylinder gear; if the tympan is practically inelastic, and if the design

and workmanship of the interacting parts are practically perfect, then the printed sheet may be of the first order. But such an aggregation of conditions are not at all times obtainable, as attested by the fact that types and engravings are more rapidly worn down under cylindrical action than under platen contact. Theoretically perfect rolling contact, as between a type-bed and a cylinder, is demonstrably unattainable; at the same time, the degree of perfection reached by cylinder press makers is remarkable. But this illustration is for the purpose of comparison only, as the field covered by cylinder presses is quite distinct from that of platen machines, and the use of the two are in many cases not interchangeable.

In a platen machine, if the surfaces of both the bed and the platen are practically plane surfaces and parallel to each other; if, with respect to the work to be performed, they are practically rigid; if the movement of one to the other is direct, square and accurate, and if there is adequate impressional power, then the printed sheet may be of the first order; the abrasive action upon the printing surface will be of the slightest possible amount, and the durability of the form will reach its maximum.

To produce a faultlessly printed sheet, at least the following elements must be aggregated: press, ink, paper, form and make-ready; and if each and all of these elements are of the first order, then the result will be the best obtainable in the least time. Should any one of these elements be defective, however, the result will either be reduced quality of product in the same time, or a high grade of product, but in longer time. It is almost, if not precisely, like the ever-occurring problem of power and motion: to obtain one you must give the other.

In fine letter-press printing, the proper delivery of the ink to the face of the form is indispensable to good work. Generally speaking, printers call or refer to this as "distribution of the ink." This means the grinding, rolling or rubbing down of an exceedingly dense, pasty mass into a uniformly thin film, and then, with the utmost delicacy in some cases, to transfer such a film to the faces of the types. So, too, an important element in connection with the distribution is the "ink fountain," employed to feed automatically the ink from a reservoir to the rollers.

In printer's parlance, to prepare a press for printing is to "make ready," and this is ordinarily the duty of that most important func-

tionary known as a "pressman." It is, in itself, a distinct art; a something which cannot be acquired except by actual painstaking trial. The delicacy of touch, the close judgment and the artistic sense displayed by pressmen of the first order entitle them to take high artistic rank. "Making ready" may be likened to the art of straightening rifle barrels or saw plates. Thus, there are those who can strike just the right blow to bring out the kink and no more, who yet may not be able to tell the reason why the desired result was obtained. On the other hand, they who may divinely elaborate the theory of the proper character of blow to be delivered, and may select the proper spot to hit, might add another kink at every clip if the hammer were plied by their hands.

In color printing, where a number of separate impressions are made upon a single sheet, the matter of "register" is of supreme importance. The full meaning of the term "register" as referred to a press, is that the action of the platen shall be so nearly perfect as not to produce a shifting movement upon the sheet. This is not to be confounded with a "slur," which may be otherwise caused, as by a loose or "baggy" tympan, or imperfectly adjusted frisket fingers.

In crank-action presses, the connecting rods and parts attached thereto are restraining members up to the dead center, but become active, driving or transmitting members after the center is passed. That is to say, the parts primarily in tension or compression act like springs to drive the gears, after having passed over the crank-center. Hence, if there is any lost motion, it will be taken up with great rapidity; consequently, back-geared crank presses require close fitting, else there will be a sharp hammer-like shock as the crank pins pass over the nip. In fact, by such shocks, cast-iron gears are frequently broken when the cause is otherwise assigned.

The somewhat remarkable circumstance has repeatedly been observed, that presses used under heavy strain will stand satisfactorily at rapid rates of operation when they will fail if operated at a lower rate of speed; and this, notwithstanding that all the conditions in each case are precisely alike, except, only, as stated, the change of speed. We have no good theory to offer in explanation of this fact, but it is a fact beyond all cavil.

So, also, a form of large area, requiring an exceptionably heavy impression, may not cause the immediate failure of the machine, which is

much more likely to occur under a lighter impression immediately following the heavier; provided, however, that the lighter impression shall be upon a form of materially less area than the first. Probably the good reason for this is to be found in the change of the distribution of strains.

In presses for cutting and scoring paper box blanks, it has been found that if the knives are permitted to take the impression without feeding the sheets, making a direct impingement upon the cutting plate, the sharp edges are much sooner turned than when, as in regular use, they are first driven through the sheet, and thence are arrested by the face of the steel plate. Whether this is simply due to the greater pressure imposed upon the edges, when the obstruction due to the sheet is missing, or that the edges of the knives are cushioned by particles of fiber carried forward under the edges of the knives, is not definitely settled. But as to the definite practical fact there is no question, even although it waits upon a laggard theory.

To emboss a sheet of paper generally requires, it is believed, more pressure upon each unit of surface than would a sheet of metal of corresponding thickness; the reason being that metal, if simply indented, would retain the form, while the fiber of paper, being resilient, must be crushed, deformed, "set," before it will take and retain, sharply, the impress of the die. In some instances, too, no amount of mere pressure will alone suffice; heat must be added to pressure, to co-act therewith, and especially is this so in fibers charged with "sizing," such as are used on book-covers.

An embossing press, running at high speed, strained up to all the fly wheel will carry over, might well be held liable to indictment for inflicting cruelty upon iron and steel; the duty, to say the least of it, is exceedingly severe, much more so than is usually apprehended.

For some years the belief has been entertained that one reason why embossing seems to require, at times, a degree of pressure apparently quite out of proportion to the result obtained, is due to the confinement of air in the cavities of the die; such cells being formed by the paper as it is driven "home," hence, the resilient air acts as a cushion and prevents an absolutely hard contact between the paper and the metal. So far, no adequate remedy has been found for this difficulty. The expedient occasionally employed in drop-forging dies, that is, minute perforations, is not usually applicable in this case.

Development of the Present Machine.

In the briefest outline reference will first be made to the press with which the writer was first connected. This was known to the trade as the "Universal," for over 15 years built by the Colt's Patent Fire Arms Manufacturing Company, of Hartford, Conn. The manufacture of this press was first undertaken, however, by the firm of Messrs. Hamilton and McNeal, at Rochester, N. Y., under patents taken by the (then) Rev. Merritt Gally. The press in several respects was novel but was unskilfully carried out from an engineering standpoint, and, as a consequence, the enterprise resulted in financial disaster, completely wiping out the considerable fortunes of the manufacturers.

The Colt's Company, together with Messrs. E. V. Haughwout & Company and Robert Coddington, Esq., of New York, and subsequently the writer, eventually became interested in the press, corrected a number of its radical imperfections, and turned out a satisfactory machine, of which about 2 500 in all were made and sold. About seven years ago, however, its manufacture was voluntarily abandoned by the Colt's Company, and the writer's present machine, known to the trade as "The Colt's Armory Press," superseded it. And these machines have ever since carried on their side frames, with distinction, it is believed, the company's famous fire-arms trade-mark—the figure of a *Colt*, rampant.

Platen Printing Presses.

The character of platen motion employed in all platen printing presses may be broadly included in two systems—those which rock or roll on a plane and those which vibrate or swing on a fixed axis. The late George P. Gordon, a well-known and successful platen press maker, was the probable originator, broadly, of the rocking platen movement in its application to printing presses. It is shown in an American patent issued to him in 1861.

The advantage peculiar to the rocking platen motion is, firstly, that the lower edge of the platen, *i*, Fig. 1, is carried outward and upward at the same time that the upper edge, *s*, is carried outward, and *vice versa;* whereby a very wide opening is obtained from a short crank radius ; and, secondly, in the ability to change the rocking motion to a direct sliding movement. The consequence of this is, that a direct impact is made upon the face of the form. In all vibrating lever or

link motions, the contact upon the form is angular, therefore tending to crowd the type off their feet, or to spring the platen or the bed, or both. But rolling platen actions, however, have been found exceedingly difficult affairs to manage properly.

Edward S. Renwick, Esq., C. E., M. Am. Soc. M. E., the eminent mechanical expert, in his recently published book, "Patentable Invention," brings out with great force and clearness how the value of an invention, or the importance to be derived from the pointing out of a defect, may be misjudged "after it has been made"; and that an opinion "formed after the event" may be quite a different thing from that

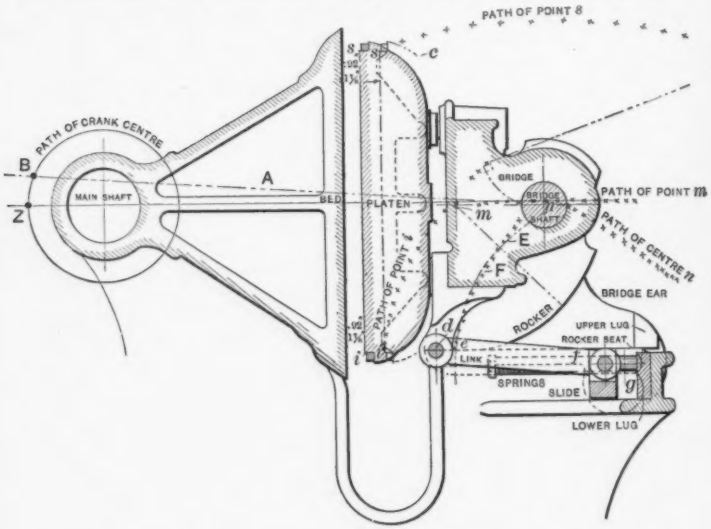


Fig. 1

formulated before it, the thing accomplished, grew to be "obvious." Now, the fundamental defect in the earlier controlling devices undoubtedly came from a misconception of what was taking place in the device *when in motion*, and a fair possibility of its correction would have been opened by this simple criticism: every point in a mass rolling upon a plane surface travels in some form of a cycloidal arc and may be entirely opposed to the action of a device moving in the arc of a circle. But this criticism was not made—fortunately so, the writer is is selfish enough to say—for the omission thereof is probably the cause

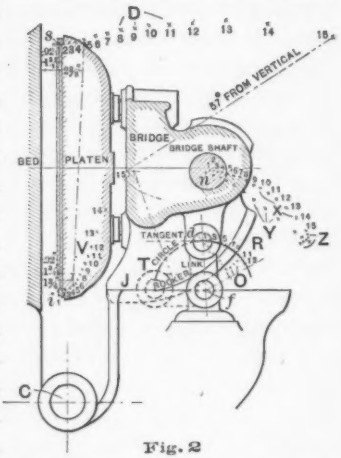
of his presence on this occasion. And thus it is that "the realm of an idea may often be defined by geometrical lines."*

In the early design of the "Universal" the platen was controlled by a single helical spring contained within a barrel and vibrating therewith. The assumption was that the rockers of the platen made rolling contact upon the seats; but the fact was that the rockers were not only forced to slip and roll differentially, but the slip, at times, was in a direction opposed to the natural movement. Then as the spring, swinging with the platen, was required to withstand the stress directly, its failure was frequent; and when it failed the entire machine was liable to be smashed, as it frequently was. The spring control shown in Fig. 1 proved as satisfactory in practice as could be expected from any spring device. The arrangement of the springs and slide rods to remain stationary was due to the late C. A. Davis, of the Colt's Company, but the plottings and disposal of the link centers were first made as here shown by the writer; the object being to so situate the swinging center, *d*, that the arc of the circle, *E*, described thereby, should, as nearly as possible, coincide with the cycloidal arc, *F*, which the said center, *d*, would develop if the rockers were free to roll upon the seats. In the direct slide to the impression the springs were compressed, the lugs acting to ensure a parallel movement. A strong objection to this method of control was its noisy operation, due to the practically instantaneous conversion of the rocking movement to the direct or tangential action. In this figure the center line, *A*, represents the main connecting rod, and *B* the center of the crank pin as the platen makes its initial contact upon the form. This indicates the fundamental defect of all simple crank or toggle presses; that is, the applied strain is never at precisely a right angle to the face of the platen until the crank, *B*, reaches the dead-center *Z*. Obviously, the tendency of this is to tilt the platen so that its face shall be normal to the strain. This tendency is restrained by the lugs of the bridge ear which engage upon the rocket seat. It will be apparent that the greater the distance of the lugs from the face of the platen, the more complete will be the control. In this design they were too close, relatively, to the platen, developing a tendency to cramp.

In Fig. 2 is shown an attempt once made to control a rocking motion by means of a link, one end secured to the platen and the other

*Dr. Draper.

to the frame, so that the platen was to slide in a tangent when the upper end of the link was swinging in the arc of a circle. There seemed to be the same abhorrence here between the two geometrical conditions as that alleged to exist between Nature and a vacuum. At any rate it proved impracticable, notwithstanding it was originally said of it that while it might not coincide with fine drawn theories it was "good enough, practically, for printers." It has recently been rearranged, with springs. This device has been shown to point the moral, as the eminent mechanician, Professor Reuleaux, has intimated, that the "bravado" in machine construction knows no limitation, and that there is absolutely no excuse for the modification of a device already well established, free for use and fairly acceptable, unless the change carries with it a definite improvement; whereas, if the change is retrograde it becomes an engineering crime, in that all are thereby caused to suffer.



At *C*, Fig. 2, there is indicated the vibrating principle of platen movement, in respect of which no time will be consumed, except to assert that it is obviously fundamentally imperfect, in that the impressional contact is angular, or as if imparted by a pair of scissors. It is sometimes facetiously referred to in the trade as the "clam shell" movement. This principle, however, has been widely adopted in a great variety of modifications; and here an important lesson may be learned, namely, that a theoretically defective device may long continue in use, and that, too, with fairly satisfactory results, provided, as is the fact in the instance at hand, that the relative degree of the error is small.

Fig. 3 is a reproduction of the drawing appearing in a patent for a mechanical movement granted to the writer in 1885, which had for its object to show in the broadest manner a new method of controlling the action of a curved body 3, rolling upon a plane 2, or the arc of a

curve rolling upon another arc. This is obtained by cams 9, 10, attached to the curved body and moving therewith, while the cam rollers 6, 7 are mounted upon the side 1 of the plane.

As this movement appeared to be entirely novel, no references of any kind ever having been found against it, and has had considerable commendation, at least from geometers, it is thought that the following quotation from the patent specification, originally drawn by the writer, may be of interest:

"It will now be apparent that if the arc be rolled back or forth upon the plane the character of the action, that is, whether rolling on the plane or a combination of rolling and sliding, will be governed entirely by the shape of the cams; but as the end here sought is to maintain a

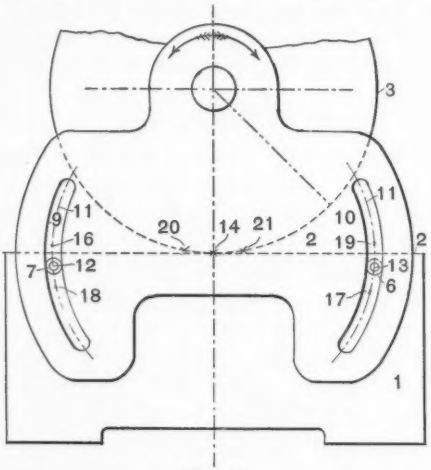


Fig. 3

perfect rolling action, the mathematical condition necessary to effect this is, that only one point in the curvilinear planes 11 of the cams shall coincide with but a single point on the surfaces of the arc and the plane on which the arc rolls, that is, by demonstration, the points in the planes at 12, 13, bisecting, if it may be so expressed, the center of the rolls can only be at that position when the point 14 of the arc is in the vertical line of the plane. With the points 16, 17, or 18, 19, bisecting the centers of the rolls, we should then find the points 20, 21 of the arc in the vertical line, and so on. As there is but one system or class of curves known which meets this condition, the statement of the problem in effect answers it, namely, that the required

form of the cam or cams shall be that of a cycloidal curve, in the projection of which the arc is the generating circle, the plane surface is tangent of the generating circle, and the fixed roller the describing point. I have just referred to the required form of curve as a 'system or class.' This is correct, in that the curve of the cams would only be a cycloid in its strictest interpretation when the center of the friction rollers exactly coincided with the plane on which the arc rolls; but as the principle involved in the projection of the curve is the same in any instance, whether the describing point be on the circumference of the generating circle or within or without the said circumference, or be the point in the plane on which the generating circle rolls, or above or below it, or whether the plane were also a curved surface (in which instance the curve would be an epicycloid), the result produced would be one and the same in every instance. The plane may be rolled upon the curve, in which case the friction rollers would traverse the cams. The term 'plane' as herein employed is used in its broadest sense, without limitation as to rectilinear or curvilinear projection."

In Fig. 4 is shown the practical application to a platen *A*, having

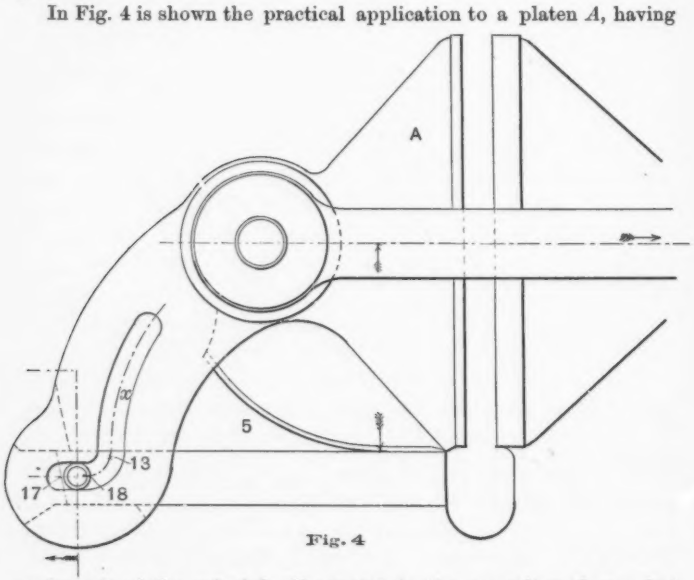


Fig. 4

rockers 5, of the principle illustrated in the preceding figure, but with two important additions. First, the arbitrarily curved section between 13 and 18, joining the cycloid x on the one side, and also,

second, joining the tangent 17, 18 on the other. In this wise, the rocking movement conforming to the cycloid is gradually merged by the curved section, without the slightest shock or jar, into the tangential portion, thus permitting the platen to slide with perfect freedom and parallelism to and from the form.

"In this manner," to quote again from specification records, "the movement of a mass which may weigh hundreds of pounds is produced with practically no friction during the chief—the rolling—portion of the motion, while the said rolling motion is converted into a reciprocating sliding motion without noise, shock or material wear of the parts. The rocking block is also positively locked against displacement in every position which it may occupy, so that it cannot slide during the time when it should rock, or rock during the time when it should slide."

In Fig. 5 is shown the first application of the new controlling device, the cam being made as a separate part attached to planed seats on the platen bridge and on the center thereof. As shown, the walls of the cam are cut away, top and bottom, at the right hand of the tangent of the curve, corresponding to the direct slide just prior to the impression, so that the cam and its roller are never subjected to severe strain, but simply act to ensure the proper rolling motion of the bridge and platen. The duty required of the cam is very slight, in that the thrust upon the roller is constant, changing only when the motion of the platen is reversed, thus ensuring the durability both of the cam and of the roller.

The aforesaid figure also shows what was termed the dwell-cam 28, attached to the crank pin. The eyes of the connecting rods were slotted so that the crank pins could traverse back therein. In this wise the platen would be driven by the crank pins from the vertical position to an angle of 45°, as at 40, whence the dwell-cams would assume control, carrying the platen still further out, as to 46, an angle of 68°, and at this position the platen would rest or "dwell," the crank pins meantime moving within the slots of the rods. The presumed advantage of this dwell-cam arrangement was that it realized a distinct gain in time and a more favorable condition for feeding the sheets.

In Fig. 6 is shown the dwell-cam as applied to the "Universal" press by the Colt's Company. This device was originally suggested by Mr. L. C. McNeal, one of the originators of the machine, but the

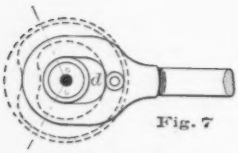


Fig. 7

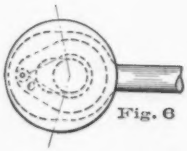


Fig. 6

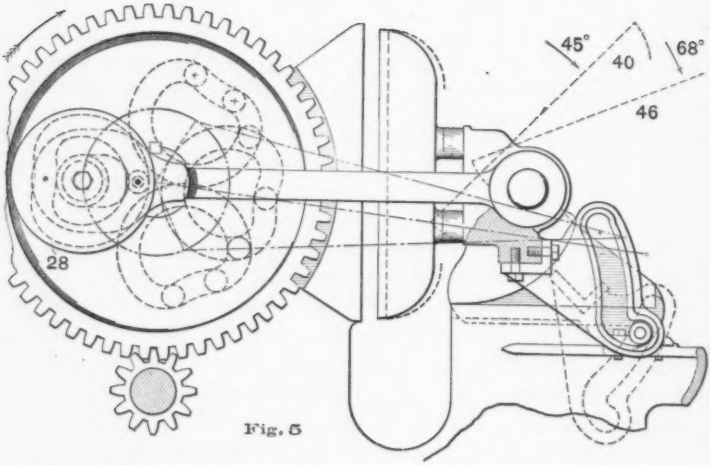


Fig. 5

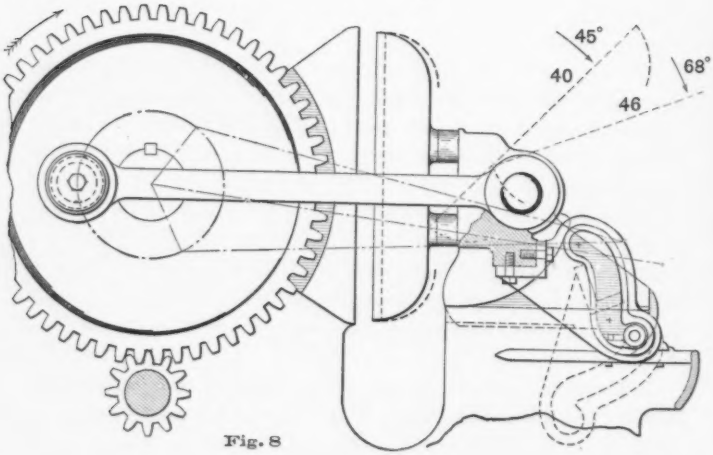


Fig. 8

form here shown was jointly due to Mr. Davis, already referred to, and to Mr. Charles B. Richards, once a Member of this Society, who at that time was the Mechanical Engineer of the Colt's Company. While the operation of this was all that could be desired when new, the original fault remained, that the roller pin *c*, being inserted in the front of the connecting rod "eye," weakened the same, and that the unsupported crank pin was unusually liable to cut and grind. This was obviated by the writer in the design shown in Figs. 5 and 7, the location of the pin being changed to the opposite side of the crank pin and a free sleeve, *d*, being applied over the crank pin. Thus the sleeve would act as a friction roll when traversing the slot, but would lock in the end of the slot and act as a bushing for the crank pin during the impression.

Up to about this time the idea was more or less dogmatically fixed in the mind of the writer that the form of the platen-controlling cam must be such as to cause rolling contact between the rockers and their seats. And thus does the rut of habit "make slaves of us all." Finally, through a thick and hardened crust, came the thought, Why not cause the rockers to slip with a constantly differential movement? It was tried between two mornings experimentally, and the final result is shown in Fig. 8. In this, by simply curving the upper portion of the controlling cam forward, the slotted connecting rods and the dwell-cams were thrown aside, and by thus causing the rockers to roll differentially and slip through a portion of their swing, the platen was carried outward, in the same time as before, to the 45° angle, while its further progress to the 68° angle was also accomplished in precisely the same time as before, but with the single difference that it was swung through this 23° space at a slower rate of speed. Not only did this simplify the machine and materially reduce the cost of its manufacture, but it increased the safe practicable feeding speed by easily 25% while the limit of its durability is not known; as up to the present time, covering an experience with over 1 000 machines, there has not been, so far as heard of, a single failure.

Fig. 9 (Plate LXX) is a half-tone illustration of a complete printing press, from the fly-wheel side. Attention is directed to the combined belt shifter and brake, by means of which a single thrust of the hand shifts the belt to the loose pulley and at the same time applies great friction to the fly wheel. The hand lever, at its lower end, extends

inwardly, like a bell crank, and at its extremity the brake shoe is attached through the intervention of a ball and socket joint. This ensures, under all circumstances, a proper contact upon the face of the fly wheel. But the brake power is especially effective because of the location of the shoe, as it will be seen that its contact upon the fly wheel is not direct, as it would be if below the center of the shaft, but makes an oblique impingement, analogous to the action of a wedge. With this appliance a boy can stop the press within the period of a portion of one revolution, when the fly wheel, weighing 150 lbs., is revolving at the rate of three revolutions a second. In this device the only mistake made, commercially considered, was that the writer did not have the forethought to apply it earlier; for when your printer-editor will look with a cold and irresponsive stare upon cams, cranks and rockers, there will come over his countenance at least a shade of warmth as he operates what he is pleased to term the "switcher." And there may be the best of reasons for this; for he may have stood in front of a swiftly moving platen, at some time, with the carriage bumping over a loose form, and no means for quickly averting disaster.

The chase (the iron frame used for locking up the form) is secured to the face of the bed by a latch, operated by the short pedal shown in the right-hand side of the engraving. Thus the chase may be quickly tilted forward or removed by the pressman, who, having both hands free, elevates or permits the depression of the latch entirely by the pedal. The pivoted guard above the pedal is to prevent accidental depression. This is swung upward by the foot when desirable to operate the latch, but it swings back automatically upon withdrawing the foot. In other words, the pressman or feeder, to operate the device, must first think.

The main connecting rods are of steel, finished by drop forging, and are produced from a solid billet of metal, without welding. This method, and the detail in connection therewith, was carried into successful practice by Mr. L. C. Grover, M. Am. Soc. M. E., Superintendent of the Colt's Arms Company. The grade of steel used is such that the average tensile strength is about 70 000 lbs. per square inch of section, with an elongation of about 20 per cent. in test specimens.

The impression may be thrown off at any part of the platen motion, by disconnecting the latch of the adjuster bar, shown at the right-hand side of the platen, and then swinging it downward with its attached

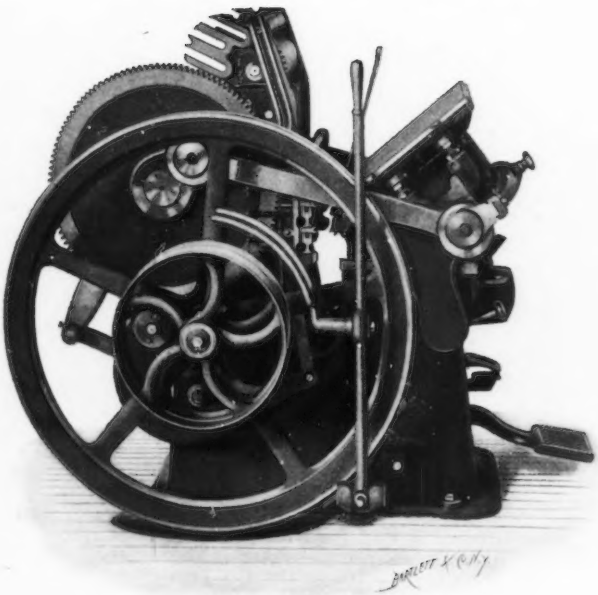


FIG. 9.—Half Medium, Style 1, Platen Printing Press.

eccentric sleeves. The effect of this is to lengthen the main connecting rods.

The plan here employed for oiling the crank pins is believed to be novel, consisting in drilling a hole lengthwise through the washer bolt to reach the cavity at the end thereof. This forms an oil reservoir. Then a hole, *A*, is drilled transversely through the crank pin, to intersect the said cavity. Consequently, at every revolution of the crank pin, the oil runs out and back again, constantly washing the bearing surface with the lubricant. Since this arrangement cut crank pins have been a rarity.

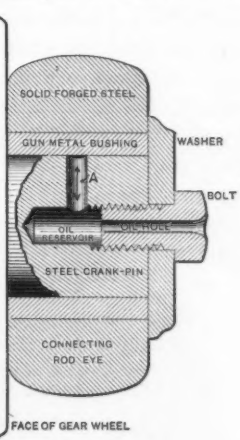


Fig. 9a.

In Figs. 10, 11 and 12 are shown the details of the ink cylinder, for distributing the ink, which result is obtained by causing the cylinder both to rotate and to reciprocate. The smaller bevel gear is fixed to the carriage-way and does not rotate. The larger bevel gear is mounted upon an arm fixed to and moving with the cylinder shaft. Hence, the larger gear has a compound movement, rotating with the cylinder and also revolving upon its own axis. The latter is termed the traveling gear. An eccentric stud upon this traveling gear carries a steel slide block engaging a slot in the cylinder. The consequence of this is, that the cylinder as it rotates is also driven back and forth, the extent of this movement being equal to the "throw" of the eccentric stud. The velocity ratio of the gears is such as to produce a relatively slow "vibration," and at a speed differential to that of the rotation. Therefore, the reversing action has little or no tendency to tear the composition rollers, although the distribution, that is, the grinding of the ink to a thin, uniform film (which simple rolling will not accomplish), is of the highest order. A point of special advantage in this action is that both the form rollers and the distributor rollers are acted upon at the same time; also that, being contained within the cylinder, no extra space need be provided. The initial driving action is derived from the spur gear, which meshes with the main crank gear, and turns the cylinder by the two driving pins, which are freely fitted

to their bearings in the cylinder, thus permitting it to be slid back and forth. Two errors of judgment were made in the first design of this device. First, in driving the cylinder by a spline in the cylinder shaft, this not having sufficient bearing surface. The two pins, driving right and left, balanced, were a complete remedy. The second error was in not confining the revolving spur gear endwise to its journal. By this omission the thrust of the gear was borne by the faces of the slot in the cylinder; hence, when the work was unusually heavy, these gears were liable to fail. This difficulty was entirely obviated, however, by confining the revolving gear to its shaft, making it a self-contained structure, by means of an end plate not shown in the engraving.

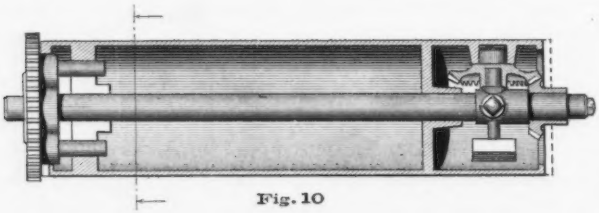


Fig. 10

Fig. 11

Fig. 12

DETAIL SECTIONAL VIEWS OF INK DISTRIBUTING ACTION.

The half-tone, Fig. 13 (Plate LXXI), is to show the detail of the ink fountain, also the apparatus for actuating the carriage which carries the form-inking rollers. The operating parts of the fountain are best shown in the detail view, Fig. 14, but will not be closely described in all of their detail. The spiral spring, acting upon the arm of the vibrator frame, swings the ductor roller from the fountain cylinder over to the main ink cylinder. A spring is here employed by preference, as it secures an elastic contact upon the main ink cylinder and allows for the considerable changes in the sizes and form of the composition rollers, which not infrequently shrink nearly 10% of their diameters. These

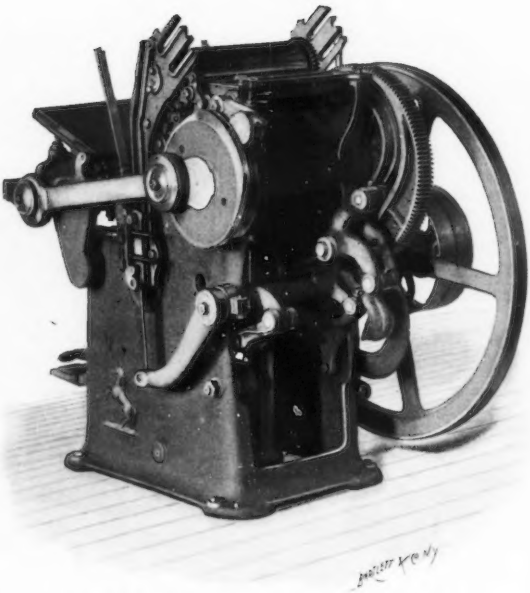
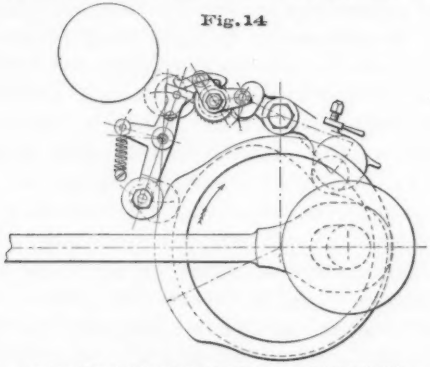


FIG. 13.—Quarto Medium, Style 1, Platen Printing Press.

movements are accurately timed, relatively, so that the contact of the ductor roller upon the main ink cylinder takes place as the carriage starts on its down motion; thus the supply of fresh ink from the ductor roller is distributed during the time that the form is being inked; while, conversely, the ductor is at the fountain while the form

Fig. 14

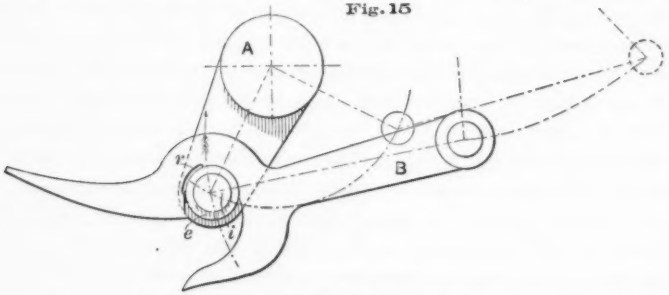


DETAIL VIEW OF APPARATUS FOR OPERATING THE INK FOUNTAIN.

rollers are upon the cylinder. The feed may be instantly stopped or started, without stopping the press, by simply swinging the ratchet pawl in or out of engagement. So, too, the number of ratchet teeth to be engaged may be quickly changed by adjusting the thumb-screw in the main driving lever.

Fig. 15 shows a detail of the carriage action. In these presses the

Fig. 15



DETAIL VIEW AND DIAGRAM OF THE HOOK-CONNECTION.

carriage may be stopped upon the cylinder by simply drawing the projecting handle, which is shown on the left-hand side, front, of the frame,

Fig. 9. The advantage of this is, that the ink may be thoroughly distributed upon the rollers while the form is in the bed, the press being operated without smearing the form. The device is positive and may be operated at any time, either to engage or disengage. In this connection, the chief feature to be pointed out is shown in Fig. 15, and consists in the application of the steel friction roller *e* to the hook pin and recessing the quadrant *r* of the hook. In the earlier movements of this character the hook made direct engagement upon the pin *i*, the consequence being that both the pin and the hook wore very rapidly and developed excessive lost motion. Besides, the circular sweep of the rocker shaft *A* had a provoking tendency to lift the hook out of engagement with the pin. By the present arrangement the hook is forced to stay in proper engagement and the wear is almost entirely confined to the pin.

The writer may say that the definite location of the fault in this device, the discovery of why the hook might properly maintain its engagement for 99 operations, and then in the case of the 100th would apparently lift itself out of gear, and, like a balky horse, without reason, simply quit, was one of the most perplexing problems he ever had to deal with. Presses were closely watched in operation, for hours at a time, the automatic disconnection going on at irregular intervals, until finally one of the watchers threw up his hands, saying: "Well, I give up; it must either be a devil or a hoodoo." But it was neither; and here is a word for theoretical demonstration. The writer firmly believes that the movement might have been watched for a year without discovering the cause; for, upon a more careful plotting, in a drawing of large scale, he discovered not only that the swing of the rocker-arm shaft was making a perfectly legitimate effort to roll the hook out of its engagement, as indicated in the drawing by the arrow, but that this was augmented by the fact that the thrust contacts as between the two arcs were favorable to the fault; that there were two tendencies at work at times to produce the fault. Theory having pointed out the cause, the practical remedy was almost obvious; at any rate, the desired result was obtained by a few strokes of a half-round file; consisting, as shown, in removing the quadrant *r*, which was the field of the interfering action.

The movement of the carriage back and forth over the form has been the subject of the greatest care and attention, whereby to effect a

perfectly cumulative start, reverse and stop, with such a disposal of the motive mechanism as to ensure durability at high speed of operation. This action is derived from the cam formed in the inside of the main gear, best shown in Fig. 13. The detail of this cam and its development will not be described, as it involves only the work which any competent engineer ought to be able to carry out. There is one feature here, however, which may be adverted to, corresponding somewhat to the transition curve theory of railroads, namely, that all cams should have their starting point materially farther back and their entering curve of materially greater radius than might appear called for theoretically. The reason for this is, that the point marked for the theoretical divergence from the concentric arc or the tangent is seldom if ever the position at which the actual initial divergence takes place; for the reason that, although the mathematics of the plan on paper may be perfect, in actual mechanism the lost motion and spring of parts are often sufficient to neutralize the easement. Hence, when the deflection does take place, it is at too rapid a rate of speed, and the result is a shock or undue wear of parts. Ergo, if there were no lost motion and greater rigidity in railroad cars, would not many of the present curves have ample easement?

Fig. 16 is a diagram which may be of interest even to those somewhat familiar with printing, and it is to show the reason why a hard "tympan" (that is, the sheets used on the platen to cushion the impression and on which to make ready) will, other things equal, be easier on the type and produce a better effect than when a soft, yielding tympan, a pillow, is employed. Obviously, when a type is forced into a yielding tympan, as shown, it not only indents the paper, but quickly rounds off the sharp edges of the type; whereas, the sharp, square type coming into accurate contact with the hard, inelastic tympan, will represent contact under pressure, but without abrasive action. So, too, the type marked "underlay" indicates the best method, when permissi-

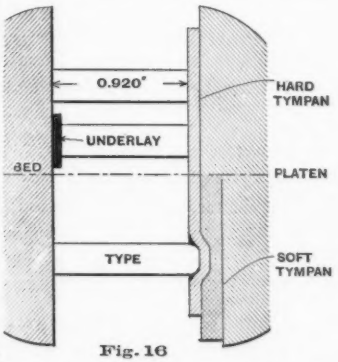


Fig. 16

ble, of correcting a defective impression, which is to bring the low types up by packing from below, rather than by "overlaying" on the tympan. The printing of daily newspapers is not included in the foregoing. In such work "blankets" are used upon the impression cylinder, and punching would be a more appropriate term than printing.

The diagram, Fig. 17, is intended to represent the delicacy of contact and perfection of movement necessary to ink properly the now widely used "half-tone" engravings. Thus, not infrequently the

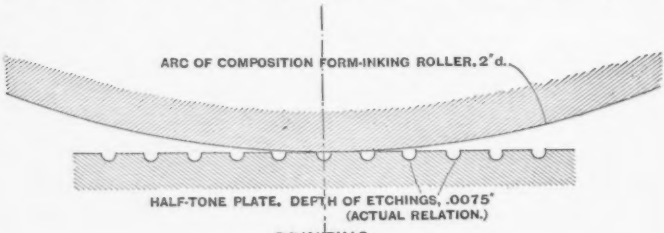


Fig. 17

height of the points bear a relation to the form roller of as 1 : 1 000, and it will be apparent that the slightest fault in the distribution of the ink or "drag" of the rollers as they pass over the engraving would result in filling the recesses, causing a smudging of the sheet.

Fig. 18 (Plate LXXII) represents a special press adapted to a combination of purposes. This machine is provided with double steel-section gears and double fly wheels. The shafting, crank pins and connecting rods are as heavy as can be swung in the space available. Comparatively few of such machines have heretofore been made, the demand necessarily being limited; but in several instances a single machine has been adapted to produce the following range of work: embossing, book-cover stamping, with either hot or cold dies; book-cover inlaying, wood printing, up to 1 in. in thickness; cutting and scoring of paper blanks and any variety of color or letter-press printing.

Embossing Presses.

Next in order of importance come presses adapted for embossing. The lighter grades of work may occasionally be executed upon platen printing presses, but even when constructed in the strongest and most

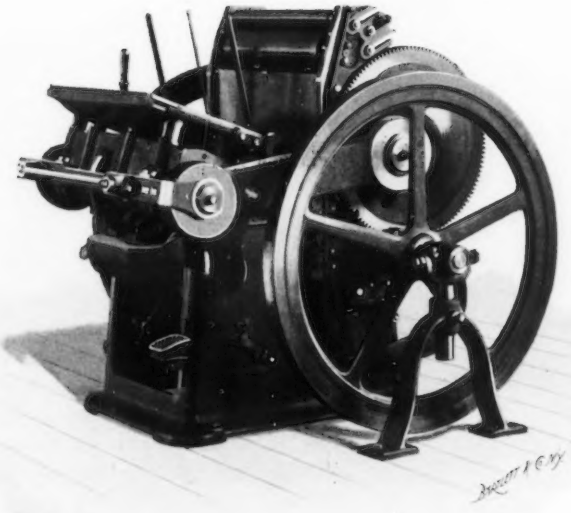
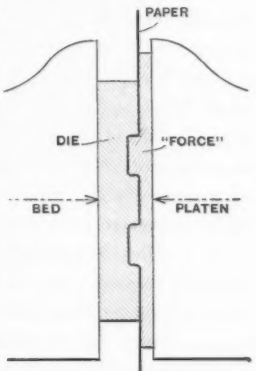


FIG. 18.—Combination Platen Printing Press.

rigid manner the usual effect of embossing is to lower more or less the efficiency of the machine as a printing press, the reason for which is, that the hard pounding, the hammer-like shocks, often experienced in embossing result in hollow beds and platens. Moreover, frequently the heaviest impressions are imposed upon dies of small area, thus centralizing the strains upon a small surface. In embossing practice, a heavy die is not necessarily of large dimensions, as its "heaviness" is much more dependent upon the number and character of the lines or points to be brought up in the paper than in the mere upsetting of blank surfaces having greater area.

Another condition of unusual severity to be contended with in embossing is, that dies may frequently be set out of proper center. Sometimes this cannot be avoided, but most frequently it is caused by error of judgment in the pressman. The cause of this is that the proper center of a die with respect to the platen may not be its lineal center. What is here meant by the term "proper center" is the center of pressure, to determine which, in regular practice, is largely a matter of experience and judgment. Thus, to cite a simple example, if a die 6 ins. wide by 12 ins. long has twice the amount of line work in 6 ins. of its length than it has in the other, then this end will require twice as much pressure as the other; hence, to balance the strain upon the press, upon this basis of 2 : 1, assumed either as of pressure or of leverage, the transverse center of such a die should be 4 ins. from the end of its heavy surface.



EMBOSSING.
Fig. 18¼

Still another reason why paper embossing involves very heavy pressure is that but one die is used; a fact, by the way, which is not infrequently unknown even by printers of experience. Thus, the real die, which is usually cut in steel or brass and occasionally etched in zinc, is a sunken figure, an intaglio, while that which would correspond to the "male" die is termed a "force" or "counter," and this is invariably built up artificially, as will be understood by reference to the diagram, Fig. 18¼. In the construction of "forces" many substances are used, such as paper, with marine or

fish glue; waxes of various kinds, cements, shellac, clays, gutta-percha, fibers, hard rubber and the like. But it can be accepted as a principle that some kind of resilient substance is essential; for, even if it were practicable to produce a perfect metal "counter" (and this has been tried by electrical deposition), it would fail, because it is improbable that any machine can be built so rigid, under strain, but that it would act to cut the sheet. In this character of "make-ready" much depends upon the skill of the pressman; one man will produce a satisfactory result with 20 tons of pressure, where another man would hardly do more than indent the paper with 100 tons. The nub of the whole matter is to get the pressure into the recesses of the die.

Fig. 19 (Plate LXXIII) illustrates the writer's most recent design in this class of machine, and, although its platen dimensions are but 12¼ x 18 ins., the press weighs about 3 200 lbs. It is a solid mass of iron and steel. Figs. 20, 21, 22 and 23 should also be referred to in the following description.

The peculiarity which establishes the designation of this press, "eccentric action," is that the platen is actuated by eccentrics instead of cranks, these eccentrics being formed upon the inside faces of the gears and projecting inwardly through the main connecting rods, which latter are thus interposed between the finished side of the bed and the finished faces of the gear wheels, the space being just sufficient to permit free movement. In this wise the shafts and main connecting rods are brought to an almost perfect shearing strain, the impressional stress being applied with such directness as to avoid spring, end-thrust or side cramp. The gears, being outside of the rods, can thus be made of almost any desired diameter, permitting a high relation of single-pair gearing. The sides of the bed do not require to be recessed to receive the gears; hence, are carried out flush with the rods.

It is believed that this represents a fair approximation to what has been well termed "the anvil principle" in machine construction. The practical benefit to the embosser is the facility with which the job may be made ready, and its long life when so completed, as there is less tendency to "crawl," a fault which quickly breaks down the fine lines of the force.

The platen motion is similar to that of the printing presses, that is, a direct slide to the impression positively controlled by interlocking lugs. The extent of the direct motion is ⅝ in. But there is one im-

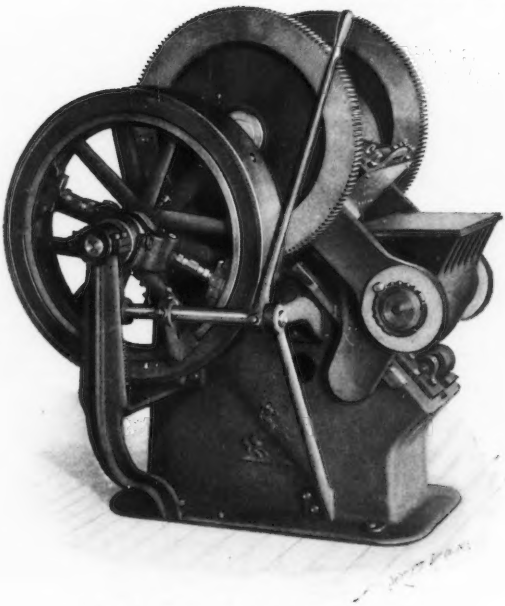


FIG. 19.—Eccentric Action Embossing Press.

portant modification. The rocker seats being inclined to an angle of 45°, the platen is thus virtually suspended by the connecting rods, the rockers sustaining but a portion of the weight of the platen. The rockers are developed from the center of the shaft. These conditions were all favorable to forming the bridge cam in such manner as to

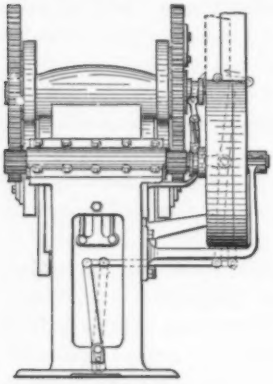


Fig. 20

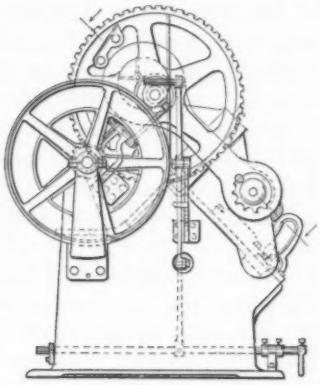


Fig. 21

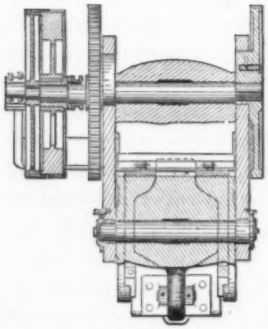


Fig. 22

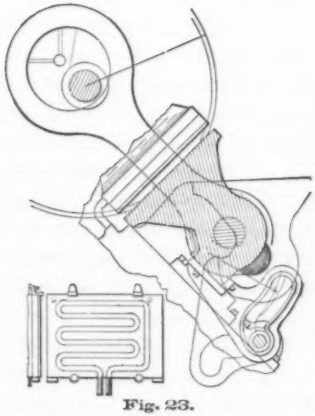


Fig. 23.

swing the platen differentially on its shaft in unison with the travel of the eccentrics, so that the "throw" of the eccentrics is augmented to the extent that the lower edge of the platen is carried outward in a line practically parallel with the face of the bed. Two important ad-

vantages are thereby obtained. First, the entire face of the platen is, as it were, lifted out and up to the feeder; and second, the radius of the eccentrics is reduced to a minimum, in this machine being but $2\frac{1}{8}$ ins. But for this design of the bridge cam the radius of the eccentrics would have required to be at least $3\frac{1}{2}$ ins.

The bridge in this press is also the platen, that is, instead of being made in two parts bolted together, one solid casting comprises the two functions. It is heavily ribbed to resist compression in front, with elliptical formation at the back to resist transverse and tensile strains.

The platen may be carried back or forth through a range of $\frac{1}{8}$ in. in 10 separate adjustments, by means of the eccentric sleeves positively locked to each connecting rod. Thus the center of strain through the platen is never altered by changing the rotative positions of the sleeves.

The bed is inclined forward to an angle of 45° from the vertical. The platen is caused to swing outward and upward to within 5° from the horizontal. In this manner the face of the platen presents itself to the operator like a table, and although 40° of swing is unusually short in a platen press, this machine is frequently fed at the rate of 1 800 impressions an hour.

The press is entirely self-contained, that is, every part is directly attached to the frame. The eccentrics are oiled from the outside of the gear wheels and the bridge-shaft trunnions through a slot in the bridge, consequently the connecting rods are not pierced. Oil reservoirs are formed in the gears, from which project oil holes to the bearing faces of the eccentrics, the consequence of this being that oil is fed at each revolution of the gears.

The pinions are cut solid, forming a part of the driving shaft, which is 3 ins. diameter and is mounted in a babbitted box extending across the frame. The main connecting rods are of liberal dimensions of mild forged steel.

There is a section of steel in each of the gear wheels, in which are formed the teeth that carry the eccentrics over the nip. This section is formed separately, is then placed in the mold and fused to the iron during the process of casting. The union of the two metals is usually perfect. The advantages of this construction are that the strength of the steel teeth is at least quite as great as would be obtained were the entire wheel produced from a steel casting, while in

the event of accidental breakage the wheel can be duplicated at much less expense. This mode of producing gear wheels for heavy impressional duty originated with the writer about 14 years ago, the Colt's Arms Company conducting the primary experiments, which resulted in complete success. Many hundreds have since been put into severe service without a single failure at the fuse or "weld" so far as he is aware. This is a feature which would seem to be applicable in many like cases. The construction was not patented, to the writer's frequent regret, and anyone is free to use it.

A steam blank, shown detached in Fig. 23, is fitted to the bed, the pipes pressing down, and thence back under the frame. This blank, the better to conduct the heat to the dies, is made of hard composition. It is usually arranged so that cold water may be turned on to cool off quickly. Occasionally the back of the blank is grooved to permit passage of air, acting to prevent, somewhat, the conduction of heat to the bed.

The friction clutch has proved highly effective. It is shown on Fig. 19, as recently designed and applied. The shifter handle is fitted with a brake shoe, so that, when the clutch is thrown off, relieving the press from the fly wheel and the belt, friction is at the same time applied to the web of the clutch mechanism, thereby stopping the platen at any desired position of its travel. The clutch may be operated with any degree of rapidity without danger of damaging the press, and without the slightest shock or jar in starting or stopping. But little novelty is claimed for this clutch, of which, possibly, the dominant feature is that, being a friction clutch and operating under excessively severe conditions (shock-transmission), it performs its function quite as perfectly as if a positive engagement were effected. A reason for this, it is believed, is that the parts are unusually heavy, and are constructed with a degree of accuracy not ordinarily followed out in such devices; consequently the power derived from the hand of the operator goes almost entirely into adhesive friction, little or none being absorbed in spring of parts.

Presses for Cutting and Scoring Paper Blanks Used in the Manufacture of Folding Paper Boxes.

The process of making folding paper boxes as now carried on may properly be designated not only a modern art, but a modern American

art, with which the writer has had something to do. Although the business, commercially, has reached an enormous volume, it is believed to be yet in its infancy, as the uses and adaptations, both of paper itself and the boxes made therefrom, are being constantly extended, covering all employments, such as water-proof paper for butter, raw oysters and ice cream, the higher grades for laces, candy and clothing, and those of strongest fiber for hardware, ammunition and the like.

Examples of paper-box blanks are shown in Figs. 24 and 25. The full lines represent cuts made by the steel rule, where the sheet is en-

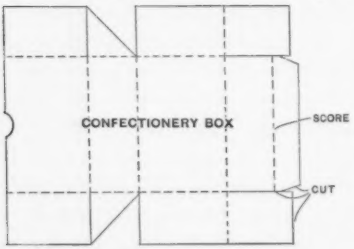


Fig. 24

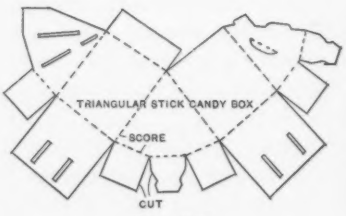


Fig. 25

tirely separated, while the dotted lines indicate the crease or kerf produced by the brass rule and upon which the blank is folded, to form a box. By this system the cut and the crease are produced at one and the same impression. One of the controlling advantages incident thereto is, that although the sheet may not be fed to exact register on the platen, the cut and score, with respect to each other, are bound to be as perfect as the die. Consequently, there is but little loss of stock as the result of careless feeding. A plurality of these blanks is usually formed at each impression, that is to say, from 2 to 20, or as many as can be disposed in a single sheet of the capacity of the machine, and this is one of the advantages inherent in a machine of large size, as the stiff, smooth paper used in box-making may ordinarily be fed nearly, if not quite, as rapidly in large sheets as in small.

The process is quite simple, consisting in setting and locking up in a chase pieces of steel and brass rule, properly disposed, to produce the desired form of blank. When so assembled it is termed a "die." The steel rule is used for cutting, and is sharpened, usually from both sides, like a "cold chisel"; the regular type-high standard—that is,

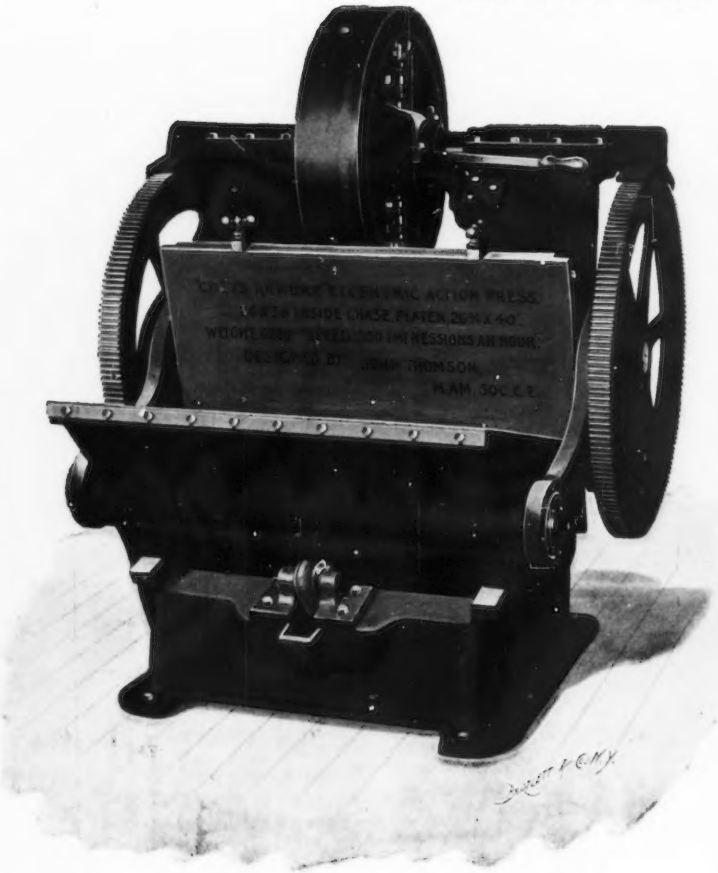
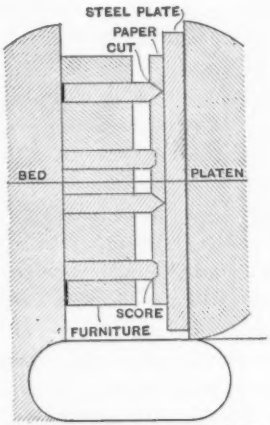


Fig. 27.—Eccentric Action Cutting and Creasing Press.

.92 in.—having come into use through the original employment of printing presses for the work. The brass rule is used for producing the crease or score, and is usually from .01 to .02 in. less in height than the steel rule. Its face may be left square or rounded, according to special requirements. The cut is made against metal plates, placed upon the surface of the platen. Tin, copper, brass, zinc, iron, steel, hard rubber and many of the fibers have been employed for this purpose, varying in thickness from $\frac{1}{32}$ to $\frac{1}{4}$ in., but the regular practice now is to use ground steel plates $\frac{1}{8}$ in., $\frac{3}{16}$ in. or $\frac{1}{4}$ in. thick. The term "ground," in this connection, means that the plates are finished bright, as in circular saws. The grade of steel is usually referred to as "soft" or "medium" saw plate.

The steel cutting rules are usually not tempered, but are planed, milled or filed, and then slightly run over by an oil stone to remove the wire edge. The quality of this material is usually designated as "hard cold-rolled spring steel."

The diagram, Fig. 26, may assist to an understanding of the principal feature of this process. Here, as in letterpress printing and embossing, the skill of the pressman is quite as essential to success as that he who handles a transit should understand how to adjust it as well as to take its readings.



PAPER-BOX CUTTING AND SCORING OR CREASING.
Fig. 26

Fig. 27 (Plate LXXIV) illustrates the latest, and probably the strongest, most rigid and largest platen machine of the jobbing pattern that has yet been designed. As it exemplifies the principles already pointed out in the embossing press, but one or two special features will be described. Thus, as shown in the engraving, the fly wheel is mounted upon the top of the bed between the gear wheels. The advantages of this disposal are increased compactness, a perfect division of the strain to the gears, and the ability to mount the clutch handle directly in front of the feeder. The bed is inclined 15°; hence, the rockers of the bridge roll back and forth upon an inclined plane. The object of this is to

bring the platen face further out, to facilitate the more rapid feeding of large sheets. These machines are frequently operated at the rate of 1 500 impressions an hour, an interval between impressions of slightly less than 2.5 seconds. The weight of the platen is 1 300 lbs., and at each reciprocation it moves through an angle of about 60°. The weight of all the parts in motion is about 2 500 pounds. The platen, to all ocular intents and purposes, may be instantly stopped and started, either during its inward or outward action, without the slightest shock or tremble.

Fig. 28 (Plate LXXV) illustrates the crank action type of paper-box cutting and creasing presses. This is a case in which "the first shall be last," for chronologically, this was the first machine of the "Colt's Armory" line of presses designed by the writer, the drawings for which were made during the winter of 1886. There was a number of things in connection with the production of this machine which was particularly gratifying. This was the first practical application of the new platen-controlling device; it was the largest platen, at that time, 21 x 32 ins., and its weight, 1 100 lbs., was nearly twice that of any prior machine of its kind; the eccentric sleeves used for throwing off the impression required to be secured to the bridge by double latches and yet to be readily detachable by one hand. Moreover, it would not be a commercial success unless it operated satisfactorily at 1 200 impressions an hour. Then, over all, the machine had been founded upon this theory, namely, if, for the work to be performed, it could be made practically inelastic, to the extent at least of ensuring simple contact and no more, between the edge of the knife and the surface of the cutting plate, then the durability of the dies would be greatly enhanced over prior practice. It may serve to make clear the importance of reaching such a condition by mentioning that a fault or spring under strain of but .001 in. in one impression becomes the equivalent of 1 in. in 1 000 impressions, and so on. Suffice it to say, that the first press built from the drawings not only met every condition predicted and served its intended purpose thoroughly well, but has also since stood as a model, both at home and abroad, for the kindergarten professors of the art. The writer may say that the first time he saw this press operating at actual work, in a New York City factory, it was being fed at 2 400 impressions an hour, that is, exactly double the speed originally contemplated. The result of this inspection was to

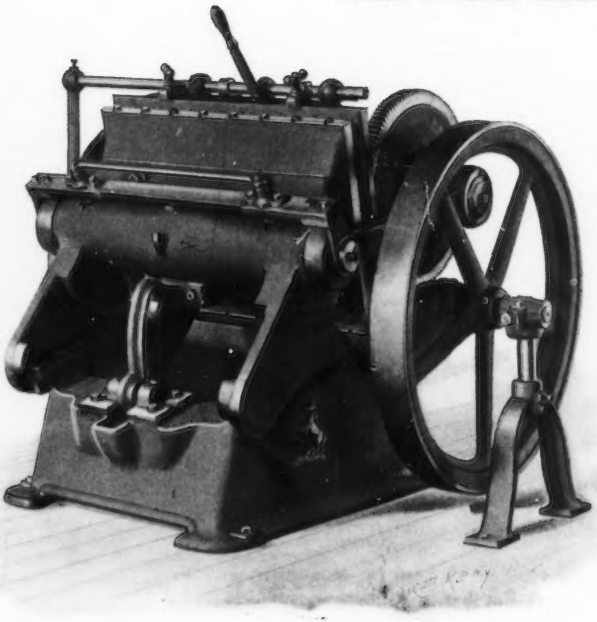


FIG. 28.—Crank-Action Paper-Box Cutting and Creasing Press.

induce that blessed feeling of satisfaction which comes to one when he has the ocular demonstration that his theory is being "sustained by practice."

MISCELLANEOUS FEATURES, WITH SOME EXPERIENCES AND OPINIONS.

The beds and frames of the presses here illustrated have been the subject of rather protracted study. As samples of decorative art work they undoubtedly are not entitled to take high rank, for each and every line has been laid subservient to but one objective—efficiency. To the writer's mind, a curly-cue line in the path of a strain is an abomination. And this reference to plain lines reminds him of a youthful experience when he was commissioned to design the case for an exceptionally fine watch movement to be presented to the daughter of the lady making the purchase. The specification closed like this: "In fine, I want the case to be as I hope the recipient will become—the outside not remarkable except as it reveals the goodness within." Upon the whole, when you follow up the logic of the question, should not efficiency come pretty near to being the real objective of the artist as well as of the engineer?

As will doubtless have been noticed, the plotting of the rocking platen motion by the graphic method would be, to say the least of it, troublesome and tedious. The writer early in the work adopted the use of paper templates, carefully marking thereon, or perforating, as the case might be, not only the essential working centers, but frequently noting arbitrary positions. Then, as the curve would be rolled, or differentially rolled and slipped upon the straight edge (this, too, usually being paper made fast to the board), the position of the several centers would be marked and given a corresponding number or letter. In this manner the work could readily be proven with accuracy while a great variety of cut-and-dry locations were easily laid out, and that, too, with considerable rapidity.

Here is a simple rule to avoid accidental breakage in machinery. Make it a hard and fast practice to have your machinery examined at stated times, and particularly observe that all stud-bolts, screws and nuts are tight and performing proper duty. Insist upon the carrying out of this simple system, and you will find that those accidents which are reported as if an effect without a cause, "broke itself, not a thing touched it," will cease; for if it had been "touched" at the proper

time, there would have been no cause for accident. The economics of railroading compels such inspection of cars and locomotives. Then it has been proved, times over, that it pays to keep machinery bright and clean, and while this is particularly applicable to a printing press, it is good practice, now and then, even in a stone crusher.

An elementary word in regard to oil may bear repeating here. The function of oil on machinery is to prevent the contact of metallic surfaces. It acts like a system of rollers. To perform proper duty, it should have sufficient tenacity not to crush; it should be sufficiently limpid to reach the surfaces of well-fitted journals and yet not "run away"; and it should not change its quality by exposure to the air or from contact with metals. Animal oils are liable to corrode; vegetable oils to "gum up." The writer does not hesitate to recommend the modern mineral oils, without doctoring or compounding in any way, as the best for regular practice, at least in the character of machinery herein referred to. If some one could devise a thumb-and-finger rule for determining the approximate quality of oil, and then promulgate it, there would result at once a distinct advance in moral ethics; for the patience of the patriarch of the land of Uz would give out under the complaint of "soft metal" when it is found that bearings subjected to tons of pressure to the square inch are being lubricated with oil proper only for a sewing machine or a clock.

Respecting the application of oil, it is better practice to apply frequently and sparingly rather than at long intervals to flood your bearings. All bearings subject to heavy strain should be frequently wiped, if open, or washed out with benzine, if closed, else the fine particles of metal which become separated, mix with the lubricant and thus form a grinding paste. And especially is this so in the first starting up of a new machine, in which there is sure to be a residuum of fine dust, filings and grit that no amount of original wiping or brushing will fully remove. Now, if this is carefully removed as rapidly as it accumulates, then the effect of the initial wear is highly beneficial, the bearings soon taking on a burnished polish, the endurance of which is of the first order.

In all closed cams, that is, in which a closely fitted roller works in a groove, oil should be sparingly applied, especially so if the oil is of heavy body, the reason for this being that the oil may act to prevent the roller from turning upon its journal.

It has proved advantageous in our practice to form all cam rollers slightly crowning. In this way, the pressure is bound to be transmitted evenly to the stud or journal, and it will be more certain to revolve under all circumstances.

It is believed that, wherever practicable, all friction rollers and crank-pin bearings and the like ought to be freely fitted sidewise, that is, having plenty of end motion, as under such conditions there is less liability to cut, or "ring up," than where no opportunity is given for the bearing surfaces to shift automatically. It is probable that a principal reason why end motion shows up, practically, as well as it does, is that it assists to distribute the oil between the working surfaces.

The query is often asked: What pressure will this or that machine give? Such questions cannot be definitely answered, it is believed, at the present time. Several years ago the writer constructed a hydraulic ram adapted to a printing press to be acted upon by the platen, its relation being 50 : 1 of a 10 000-lb. Bourdon spring gauge, alleged to have been carefully constructed for the purpose, and intended to give a maximum indication of 500 000 lbs. But the shocks soon gave evidence that the gauge tube was playing the too usual part of such instruments, and this, together with business complications, which came up at the time, put a stop to the proposed extended series of experiments. Nevertheless, enough was ascertained by the considerable number of experiments carried out to indicate a "handy" empirical method of approximating the measure of kinetic energy, in terms of foot pounds, which the fly wheel of a press would be capable of exerting upon the platen, the sole object of this being to form a premise upon which to determine the dimensions of the working parts. The indications of the experiments referred to were that the coefficient of friction, under heavy strains, was materially higher and more variable than had been expected; hence it appeared that any expression as to its value, short of absolute determination, under actual working conditions, would be little better than guesswork. The scheme was then adopted to disregard entirely the consideration of friction and simply let it stand as the factor of safety. Briefly, then, the whole matter boiled down to this: The pressure deliverable at the platen in foot-pounds (F) would be equal to half the weight of the rim of the fly wheel in pounds ($\frac{1}{2}$ M) times the square of the velocity (v^2) in feet per second at the center of its gyration divided by the impression

movement of the platen in parts of a foot, the latter most readily obtainable by finding the versed sine (S) of the crank during the angle of its impression action $\left(F = \frac{\frac{1}{2} M V^2}{S}\right)$. Thus, if it were shown that the theoretical strain which might be imposed upon the connections were up to about the tensile limit of the material, then the power absorbed in friction, be it 25, 35, 50% (any of which guesses might be good), would be the factor on the side of safety. The diagram, Fig. 29, is a reduplication of the dimensions, process and figures upon

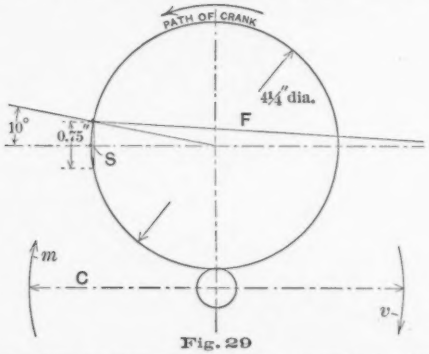


Fig. 29

Dimensions are those of Embossing Press, Fig. 19. Example: F = foot-pounds on connecting rods. S, versed sine, = .00275 ft. M, fly wheel, = 250 lbs. C, center of gyration of fly wheel, = 6.28 ft. circumference. V, velocity of fly wheel, = 17.8 ft. a second. Relation of fly wheel to crank = 8.5:1. Time of revolution of crank = 3 seconds. Cross-section of connecting rods and pins = 20 sq. ins. $\left(F = \frac{\frac{1}{2} M V^2}{S}\right)$. Thus, $125 \times 17.8^2 = 1\,440\,181$ ft. lbs., or 720 tons, if no friction, and if fly wheel were brought to rest during the 10° traverse of crank. (= .083 second).

But assume belt capable of restoring but half of full velocity, then $\frac{360}{20 \text{ sq. ft.}} = 18$ second foot-tons to each square inch of section; which is probably the greatest maximum load possible in practice and with no deduction yet made for friction.

which the embossing press, Fig. 19, was designed, and the other machines herein shown were also predicated upon this theory. All the writer will say for this method is, that the presses built under its wing have most worthily stood up to their duty. His judgment is that it is well within the line of safety, in the character of machines here shown, as in at least two instances fly wheels were subsequently increased in weight over that called for by the rule, again indicating a very high coefficient of friction under strain. Whether there is any novelty in this direct transfer from the rim of the fly wheel to the versed sine of

the crank, he does not know, nor does he much care, as, like many such expressions, it is largely an intellectual satisfaction, liable to be practically misleading. He hopes, at no far distant time, to take the subject up under the only proper method, if it can be satisfactorily worked out, as he confidently believes it can, namely, to make the measurement of the pressures in actual pounds of weight at the apex, the instant of greatest effort.

Conclusion.

The strongest incentive to advancement is to learn of the achievements made by others, and next to this is the faith of those with whom you have to treat; for it not only requires skill and experience, but patience, faith and money as well, to make a commercial success of any machine which is expensive to construct as compared with its competitors. Intention is, of course, a useful factor; but this is not all. You must first know what to do; next, how to do it, and then do it. We should all bear in mind that an incorrect principle will outlive the best steel that was ever forged. And then, too, the "little things" are so often of the most vital importance, because far reaching in their consequences. It is the obscure detail, unrecognized or passed by as of no consequence, which most often stands as the dividing line between that which shall be successful and enduring, or unsuccessful and short-lived. It was the great anatomist, sculptor, architect, painter, Michael Angelo, who said "Trifles make perfection."

Whatever may be here discovered to be defective, or whatever may be regarded as worthy, the writer is entirely responsible for; but that the early work was under any circumstances possible was due to the loyal good faith and judgment of his early associates and friends in the work, who were then officers in the Colt's Arms Company, namely, General William B. Franklin, M. Am. Soc. C. E., its Vice-President and General Agent; Mr. Hugh Harbison, its Treasurer, and the late Horace Lord, who for over thirty years was its Superintendent.

It is hoped that the engraving here presented, "The Iron-Worker and King Solomon,"* will not be regarded as out of place, as it is in-

*Permission to make this reproduction, from one of the first artist's proofs of this celebrated engraving, was specially given to the author by the owner of the copyright, for the express purpose of presentation to the members of the Society. It was at first intended to bind it in as a part of the *Transactions;* but with the view to preserve the margin better and to permit the use of heavier paper it has been decided to send it out as an insert.

tended to indicate the most advanced accomplishment in photographic "process" work and also in letter-press printing. The subject is not only happily chosen, we believe, but every detail, mechanically and artistically, is faultless. Results like this might possibly cause an improper degree of exultation upon the part of the modest press-maker were it not for the restraining claims of the ink-maker, the paper-maker, the photographer, the artist and the pressman, each and all of whom are entitled to share in the credit. Nevertheless, may he not properly take unto himself the claim, that without the printing press there would have been no Art Preservative of Arts; nay, more, that without the engineer there would have been no printing machine? Verily, we have eminent authority for this assumption, for the wisest man, when time was young, proclaimed it in express words: "Ho, there," commanded Solomon, "make place at my right hand; the claim is justly made; but for the iron-worker (the engineer) I would have had no temple!"

THE IRON WORKER AND KING SOLOMON.

PAINTED BY PROF. C. SCHUSSELE. ENGRAVED BY JOHN SARTAIN.

AMERICAN SOCIETY OF CIVIL ENGINEERS.

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TRANSACTIONS.

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741.

Vol. XXXII.—December, 1894.

THE STRENGTH AND WEATHERING QUALITIES OF ROOFING SLATES.

By MANSFIELD MERRIMAN, M. Am. Soc. C. E.

READ DECEMBER 19TH, 1894.

In a paper published in *Transactions* for September, 1892, Vol. XXVII, pages 331–349, the soft-veined roofing slates of Northampton County, Pa., were described, and results of tests of strength and weathering qualities were presented. Similar tests of other varieties of slate, and also a series of comparative impact experiments, having since been made, the following additional notes are given as a continuation of the discussion of the subject.

The increasing growth of the slate industry in the United States is shown by the following figures taken from the census reports:

	In 1880.	In 1890.
Number of quarries	94	206
Capital invested	$3 328 150	$10 042 293
Squares of roofing slate produced	457 267	828 990
Value of all slate produced	$1 529 985	$3 444 863

The distribution of the industry among the different States in 1890 is thus indicated: The value of all slate produced in Pennsylvania was $2 011 776; in Vermont, $838 013; in Maine, $214 000; in New York, $130 603; in Maryland, $110 008; in Virginia, $85 079; in Georgia,

$15 330; in Michigan, $15 000; in California, $13 889; in New Jersey, $10 985; in Arkansas, $240;—total, $3 444 863.

A more natural classification is that by regions, in each of which a quality of slate, more or less distinctive, is found. The region furnishing the most slate is that in Rutland County, Vt., and Washington County, N. Y., the product of which is largely purple, green and red slates. The other regions produce bluish black slates almost entirely. The following shows the number of quarries and the value of the product in each region in 1890.

	Quarries.	Product.
Vermont and New York region	76	$968 616
Bangor region, Pennsylvania	20	707 162
Lehigh region, Pennsylvania	45	690 432
Pen Argyle region, Pennsylvania	17	393 030
Maine region	4	214 000
Northampton hard-vein region, Pennsylvania	18	184 595
Peach Bottom region, Maryland and Pennsylvania	9	146 565
Virginia region	3	85 079
Other regions (Arkansas, California, Michigan, New Jersey, Georgia)	14	55 384
	206	$3 444 863

The physical and chemical properties of the slates of the Bangor and Pen Argyle regions are described in the paper of 1892. These, together with the Lehigh and the Northampton, hard-veined slates, are found in the extensive slate formation known as the Hudson River division of the lower Silurian deposits, which extends from New Jersey to Georgia along the southwestern slope of the Blue Mountains. The slate formations of Vermont and New York, of Maine, and of the Peach Bottom region, however, probably belong to the Cambrian division of the Archean or Azoic deposits, whose place in the geological series is lower and older than the Silurian rocks.

Vermont and New York Region.—This region is about 40 miles long, extending from Castleton, Vt., to Salem, N. Y., with an average width of about 1½ miles. Red slate is produced in Washington County, N. Y., and purple, green and bluish black varieties throughout the entire region, which are used, not only for roofing, but also for mantels and other ornamental purposes. In *Van Nostrand's Magazine* for August,

1884, are given the records of compressive and flexural tests made by J. Francis Williams, C. E., on blocks 1 in. in section. Wood and pasteboard cushions were placed between the bearing surfaces in some tests, the compressive strength being found greater than when no cushions were used. The mean results of these experiments are as follows, all values being given in pounds per square inch. The modulus of rupture is the mean computed from the breaking loads given for two different spans.

	Purple.	Red.	Green.
Compressive strength, wood cushions.....	19 380	14 170	13 140
Compressive strength, pasteboard cushions.	24 760	18 110	17 560
Compressive strength, no cushions.....	13 860	10 190	8 040
Elastic limit, no cushions.....	10 260	4 850	5 150
Modulus of rupture.....	10 800	7 310	8 840

Some impact and acid tests on the red slate of this region are described later in this paper.

Peach Bottom Region.—Of the nine quarries in this region, five are in Harford County, Md., and four in York County, Pa. The belt is about 8 miles in length, and its workable width about ½ mile; about 2 miles of this length are in Lancaster County, Pa., where, however, no quarries are now worked. The rough geological section in Fig. 1 shows the rock formations for about 50 miles in length parallel to the

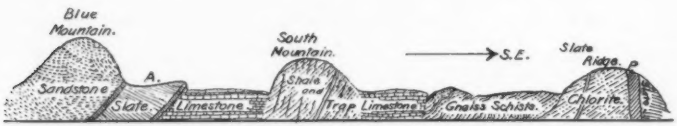

Fig. 1.

Susquehanna River, from the Maryland line to the Blue Mountains, north of Harrisburg. At *A* are the Hudson River slate deposits, which, however, have no quarries in this vicinity, and the Silurian limestone is found on both sides of the South Mountain. The Cambrian gneiss and chlorites occur further south, and at *P* is seen the narrow and almost vertical vein of Peach Bottom slates, in the hills known as Slate Ridge.

On the west side of the Susquehanna, about 5 miles from the river,

the slate outcrops on the surface. A little was quarried about the year 1800, and a stone church near Delta, Pa., was roofed with it in 1805, the slate remaining on the roof until 1893, when the church was pulled down, and the slate was sold for use on other buildings. The quarries now worked have been opened and developed since 1850; they are all open vertical pits, of various depths between 100 and 200 ft. The vein of workable slate is about 250 ft. wide at the eastern end, and nearly ¾ mile wide at the western end, the length being 3 or 4 miles.

The cleavage of these slates is nearly vertical and almost coincident with the dip, it being also parallel to the planes of stratification. The beds of clay were therefore subject to pressure normal to the planes of stratification, and the whole mass was turned into a vertical position by some violent upheaval in early geologic time. Hence ribbons do not occur in the slate of this region.

The methods of quarrying, splitting and dressing these slates are, in general, similar to those employed in the Northampton region. Quarrying is often interrupted by the inflow of water after rains. On Plate LXXVI is shown an abandoned quarry, in which on both sides are seen the so-called "joints," or splits in the rock. The joints are normal to the vertical cleavage and dip, while the "grain" of the slate is approximately at right angles to them. It appears as if the pressure from powerful horizontal forces upon the vertical vein of slate had caused tensile and compressive forces in inclined directions, the former resulting in the formation of joints, while the latter caused the grain. In quarrying, horizontal holes are drilled normal to the cleavage and in a row parallel to a joint, so as to detach a large block, perhaps 15 ft. long, 8 ft. wide and 4 ft. thick, which is split into several smaller ones before being hoisted to the surface. In splitting and dressing the roofing slate, it is always done so that the grain runs parallel to the longer side of the rectangle. This grain, although never so marked as that in timber, has a similar effect upon the strength in different directions, a piece of roofing slate being, for example, far more liable to crack lengthwise than transversely.

The compressive strength of Peach Bottom slate, as determined in 1893 by Prof. Louis E. Reber, of State College, Pa., from tests of 3-in. cubes, is 5 360 lbs. per square inch when the pressure is applied parallel to the cleavage, and 10 530 lbs. per square inch when the pressure is applied perpendicular to the cleavage.

PLATE LXXVI.
TRANS. AM. SOC. CIV. ENGRS.
VOL. XXXII, No. 741.
MERRIMAN ON ROOFING SLATES.

During the present year the writer has made tests for strength, toughness, density, softness, porosity and corrodibility on twelve specimens of Peach Bottom slate, following the same methods as described in the former paper for the old Bangor and Albion slates. The specimens were 12 x 24 ins. in size, varying in thickness from 0.21 to 0.29 in. For the test of strength they were laid on supports 22 ins. apart and broken by a load slowly applied at the middle. The modulus of rupture for each case was then computed from the formula—

$$\text{Modulus} = \frac{3 \times \text{breaking load} \times \text{length}}{2 \times \text{width} \times \text{square of thickness.}}$$

For instance, the specimen marked Q_1 was 12.04 ins. wide, 22 ins. between supports, 0.26 in. thick, and it broke under a load of 283½ lbs.; hence its modulus of rupture is 11 490 lbs. per square inch. The deflection, measured at the moment of rupture, was also noted as an index of toughness.

The density of the specimens was determined by finding the specific gravity of each. The degree of softness was found by the weight abraded by 50 turns of a small grindstone under a constant pressure of 10 lbs. The porosity was determined by finding the percentage of water absorbed in 24 hours, after being dried for the same length of time at a temperature of 135° Fahr. The test for corrodibility was the percentage of loss in weight after immersion for 63 hours in a solution consisting of 98 parts by weight of water, 1 part of hydrochloric, and 1 part of sulphuric, acid.

The color of the slate was a dark bluish gray, or bluish black, and the texture of the surface was slightly scaly and soapy, being less smooth than the Northampton varieties. When ruptured by flexure, the specimens broke square across the grain without splitting or lamination. The tests for density, softness, porosity and corrodibility were made on pieces of the ruptured specimens.

The table on page 534 gives the results of all the tests for each of the 12 specimens and also the mean values.

An examination of these results tends to confirm the conclusions announced in the previous paper that in general the strongest specimens are the heaviest and softest, as also the least porous and corrodible, although exceptions occur in the case of Q_7 and P_2, and the Q specimens seem more corrodible than the P's, although greater in strength. The tests for strength and corrodibility are probably those

Mark of Specimen.	Strength. Modulus of rupture in pounds per square inch.	Toughness. Ultimate deflection in inches on supports 22 ins. apart.	Density. Specific gravity.	Softness. Grains abraded by 50 turns of a small grindstone.	Porosity. Percent. of water absorbed in 24 hours	Corrodibility. Percent. of weight lost in 63 hours in acid solution.
Q_1	11 490	0.32	2.886	69	0.265	0.247
Q_2	12 585	0.30	2.907	115	0.197	0.197
Q_3	8 400	0.30	2.900	110	0.304	0.291
Q_4	13 430	0.32	2.893	177	0.228	0.194
Q_5	8 320	0.28	2.900	75	0.264	0.237
Q_6	12 010	0.32	2.918	67	0.209	0.200
Q_7	14 210	....	2.890	111	0.278	0.341
Q_8	13 060	0.34	2.902	67	0.261	0.240
P_1	10 520	0.24	2.912	69	0.171	0.150
P_2	9 360	0.20	2.885	53	0.143	0.226
P_3	10 470	0.34	2.858	87	0.216	0.161
P_4	11 255	0.26	2.873	80	0.155	.....
Means....	11 260	0.293	2.894	90	0.224	0.226

of greatest importance in forming an opinion regarding the value of the slate under actual conditions of service. The test for softness, although a good one for a single lot of specimens, may not serve to fairly compare lots tested at different times on account of the varying condition of the grindstone.

The chemical composition of the Peach Bottom slates is shown by the following analyses, one made by the Geological Survey of Pennsylvania in 1877, and the other by Booth, Garrett & Blair, of Philadelphia, in 1885:

Geological Survey.		Booth, Garrett & Blair.	
Silicic acid (SiO_2)	55.880	Silica	58.370
Alumina (Al_2O_3)	21.849	Alumina	21.985
Ferrous oxide (FeO)	9.034	Protoxide of iron	10.661
Water (H_2O)	3.385	Water	4.030
Potash (K_2O) and soda (Na_2O)	4.100	Alkali	1.933
Carbon (C)	1.974	Carbon	0.930
Magnesia (MgO)	1.495	Magnesia	1.203
Lime (CaO)	0.155	Lime	0.300
Sulphuric oxide (SO_3)	0.022	Sulphur	0.107
Titanic acid (TiO_2)	1.270	Titanic acid	traces
Manganous oxide (MnO)	0.586	Oxide of manganese	traces
Iron bisulphide (FeS_2)	0.051	Carbonic acid	0.390
Cobaltus oxide (CoO)	trace		
	99.801		99.909

The valuable constituents in slate are the silicates of iron and alumina, while the injurious constituents are sulphur and the carbonates of lime and magnesia. The percentages of these in the two analyses are as follows:

	Geological Survey.	Booth, Garrett & Blair.	Mean.
Silicates of iron and alumina.....	86.763	91.016	88.889
Sulphur	0.039	0.107	0.073
Carbonates of lime and magnesia...	3.319	3.066	3.192

The slates of the Cambrian formation are usually regarded as better in respect to strength and weathering qualities than those of the Silurian age, the market price of some varieties of the former being, indeed, more than double that of the common kinds of the latter. The Northampton slates investigated in the former paper take a high rank among the Silurian kinds, while the Peach Bottom specimens may be regarded as a good representation of the dark-blue Cambrian varieties. The following tabulation, giving the mean results of the series of tests of both, may hence be taken as the best comparison possible at present of the average physical properties and chemical composition of the Silurian and Cambrian dark-colored slates of Pennsylvania.

Property.	Measured by—	Silurian.	Cambrian.
Strength	Modulus of rupture, in pounds per square inch.....	8 480	11 260
Toughness.....	Ultimate deflection, in inches, on supports 22 ins. apart.....	0.291	0.293
Density	Specific gravity.....	2.777	2.894
Softness.....	Grains abraded on grindstone under stated conditions	104	90
Porosity.....	Percent. of water absorbed in 24 hours.....	0.191	0.224
Corrodibility...	Percent. of weight lost in acid solution in 63 hours..	0.496	0.226
Valuable Constituents.	Silicates of iron and aluminum, percent.....	81.88	88.89
Injurious Constituents..	Sulphur, percent.....	0.58	0.07
	Carbonates of lime and magnesia, percent.....	12.59	3.19

With respect to the relative value of physical tests and chemical analyses, it may be said that while the latter are valuable, the former can alone be regarded as giving authoritative information as to the wear of slate under actual conditions. The strength and weathering qualities of slate or stone depend, not merely upon its chemical constituents, but on the manner in which the grains are cemented together. For the determination of this a microscopic inspection is necessary, and in the absence of such the physical tests seem to carry far greater weight than the chemical analyses.

Impact and Acid Tests.—While the preceding methods of testing are readily carried on in the laboratory, they are not easily made under conditions of actual practice on account of the absence of precise weighing apparatus, and the lack of time and skill. It seems desirable that a test for slate should be devised which can be quickly applied by an architect or builder, and be used with confidence. An impact test, made by simply dropping a ball, appeared one likely to yield good results, and accordingly a series of experiments has been carried on to determine what can be done in this direction. In connection with these, a series of severe acid tests has been made on the same specimens.

Seven varieties of slate were used in these experiments. Four, designated hereafter by the letters *C*, *D*, *E* and *F*, were Silurian slates of Pennsylvania. Three were Cambrian slates, *P* and *Q* being Peach Bottom specimens, and *V* being a red slate from the New York and Vermont region.

The pieces of slate used in the impact test were 6 x 7¼ ins. Each piece was placed with the ends loosely clamped in grooved supports, so that it was approximately in the condition of a beam with fixed ends, the length between edges of supports being about 7¼ ins. and the width 6 ins. A wooden ball weighing 15.7 oz. was dropped upon the middle of the slate from a height of 9 ins., and the number of blows required to produce rupture was noted. The number of foot-pounds of work per pound of slate, expended in causing rupture, is a measure of the ultimate resilience of the material or of its capacity to resist shock, and thus is an index, both of its strength and toughness. Five specimens of each kind of slate were thus tested, and the table on page 537 gives the individual results and means.

The acid tests were purposely made severe in order to obtain, if possible, a better idea of the resistance to corrosion than is given by the previous tests of 63 hours. Seven jars containing a solution of 1 part of hydrochloric acid, 1 part of sulphuric acid, and 98 parts of water, by weight, were prepared, and, in each, two specimens of each variety of slate were immersed for 120 hours, or five days, the solution being well stirred once a day. The specimens were then taken out, dried for 40 hours, weighed, and the loss of original weight determined. The solution was next strengthened by adding the same amount of the two acids, and the specimens were replaced for another 120 hours, after

Silurian Slates.					Cambrian Slates.				
Specimen.	Thickness. Inches.	Weight. Ounces.	Number of Blows.	Foot-pounds of work per pound of slate.	Specimen.	Thickness. Inches.	Weight. Ounces.	Number of Blows.	Foot-pounds of work per pound of slate.
C_1.....	0.21	13.8	6	5.12	P_1	0.26	17.3	9	6.13
C_2.....	0.19	12.9	4	3.65	P_2	0.26	17.2	15	10.29
C_3.....	0.22	13.8	5	4.27	P_3	0.31	20.4	55	31.74
C_4.....	0.20	12.8	7	6.62	P_4	0.28	18.4	52	33.35
C_5.....	0.23	15.6	10	7.56	PP_4 ...	0.29	20.4	68	39.33
Means ...	0.21	13.8	6.4	5.44	Means..	0.28	18.7	39.8	24.17
D_1	0.19	13.0	5	4.53	Q_1.....	0.26	17.2	11	7.54
D_2	0.22	14.5	7	5.69	Q_2.....	0.27	17.8	20	13.25
D_4	0.19	12.4	3	2.85	Q_3.....	0.29	19.3	17	10.39
D_9	0.22	14.8	7	5.58	Q_7.....	0 28	18.2	6	3.89
D_{11}	0.24	16.2	6	4.37	QQ_7....	0.27	17.6	11	7.37
Means ...	0.21	14.2	5.6	4.60	Means..	0.27	18.0	13.0	8.49
E_1	0.19	12.4	4	3.63	V_1	0.21	13.0	32	29.04
E_{14}	0.20	13.5	2	1.74	V_2	0.26	17.3	215	146.65
E_{18}	0.21	13.5	4	3.50	V_3	0.21	12.9	339	310.09
E_{20}	0.19	13.0	6	5.44	V_4	0.20	12 9	55	50.31
E_{13}	0.22	14.3	5	4.12	V_5	0.25	14.2	117	97.22
Means ...	0.20	13.3	4.2	3.68	Means..	0.23	14.1	151.6	126.66
F_3	0.22	14.4	4	3.27					
F_4	0.20	13.3	3	2.66					
F_5	0.22	14.7	5	4.01					
F_7 .	0.25	16.5	7	5.00					
F_8	0.20	13.7	3	2.58					
Means ...	0.22	14.5	4.4	3.50					

Size of Specimen..... 6 x 7½ ins.
Weight of Ball.....15.7 ozs.
Height of Fall..... 9 ins.

which they were dried and weighed again. The solution was again strengthened by the addition of the same amounts of acid, and the specimens were immersed for 120 hours, after which they were dried and weighed as before. The specimens used for this purpose weighed about 1½ ozs. each, and the scales were sufficiently delicate to detect ½ grain. With two exceptions, they were parts of the pieces which had previously been broken in the impact tests.

In the following table the percentages of loss of original weight at the end of the three periods are given, the specimens being arranged in order of corrodibility, and also in the last columns the mean foot-pounds of work per pound of slate required to cause rupture by impact, and the mean specific gravities. These figures show that the specific

gravity is not a good index of corrodibility, but they plainly indicate that the least corrodible slate offers the greatest resistance to impact, although there are slight exceptions in the case of D and E. The diagram in Fig. 2, where the work of resilience is plotted as an ordinate and the mean loss of weight as an abscissa, shows this clearly to the

Specimens.	Percentages of Loss of Weight.			Foot-pounds of work per pound of slate.	Specific gravity.
	After 120 hours.	After 240 hours.	After 360 hours.		
D_2	1.06	1.94	2.74		
D_3	1.22	1.94	2.79		
Mean	1.14	1.94	2.76	4.6	2.77
F_7	1.08	1.60	2.18		
F_9	1.43	2.47	2.98		
Mean	1.25	2.03	2.58	3.5	2.77
E_{18}	0.82	1.36	1.82		
E_{20}	0.88	1.48	2.09		
Mean	0.85	1.42	1.95	3.7	2.78
C_3	0.64	1.28	1.70		
C_5	0.54	1.10	1.66		
Mean	0.59	1.19	1.68	5.4	2.78
Q_3	0 45	0.90	1.27		
Q_5	0.40	0.99	1.32		
Mean	0.42	0.94	1.29	8.5	2.90
P_3	0.32	0.81	1.12		
P_4	0.28	0.93	1.10		
Mean	0.30	0.87	1.11	24.2	2.89
V_4	0.00	0.17	0.34		
V_5	0.00	0.09	0.17		
Mean	0.00	0.13	0.25	126.7	2.81

eye for each of the periods of immersion. With regard to the progress of the corrosion with time it appears that the two are approximately proportional. A marked change in color of the Silurian specimens was noted, the dark blue becoming a grayish white after the last immersion, while but a slight change appeared in Q, and P and V

remained almost unaffected. Change in color is thus a direct index of corrodibility, both being due to the same cause.

As the result of the investigations thus far made, it may be concluded that the tests for density and softness, although of importance for slates of the same locality, are not good indications of the strength and weathering qualities of those of different regions; that the tests for porosity, corrodibility and flexural strength give good indications of

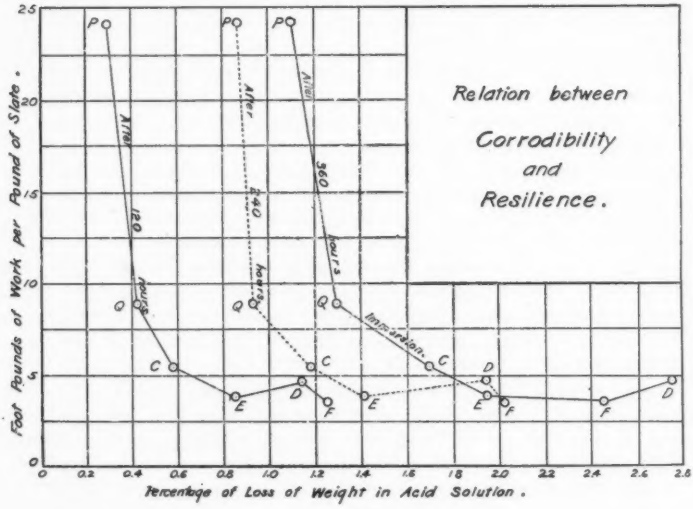

Fig. 2.

these properties; that the results found for strength and corrodibility when mentally combined give on the whole an excellent idea of the value of the slate; and that an impact test with a wooden ball shows both strength and toughness, while it at the same time indicates the capacity for resistance to corrosion. The impact test may be therefore recommended, if only a single test is to be used, as one that can be quickly and cheaply made and one likely to give reliable information of the comparative value of different kinds of slate.

CORRESPONDENCE.

GEORGE P. MERRILL, Esq.,* writes that he notes with great pleasure the fact that Prof. Merriman has been enabled to continue the good work begun two years ago, and to which reference has already been made. For some years past he has been prevented from doing any original work bearing upon the subject, but he has nevertheless retained sufficient interest in the matter to appreciate the work of others. In the two papers which Prof. Merriman has now given the Society, the subject has been gone over so thoroughly as to leave but little to be said which will bear directly upon the matter, and he may, therefore, perhaps be excused in making a slight digression.

The ordinary roofing slates occupy a very interesting position in the lithologic series. Thrown down originally in the form of fine silt on a sea bottom, they owe their fissile character, not to sedimentation, but to compressive and shearing forces as manifested in the foldings incident to the formation of mountain chains. The cleavage property is therefore in no way dependent upon the original bedding. The slates of northeastern New York, as it happens, do cleave very nearly parallel to this bedding; those in Northampton County, Pa., on the other hand, as found in various quarries, or at times in the same quarry, cleave at all angles with the bedding. Now this process of shearing, while developing the cleavage, has also brought about other structural modifications in the slate, which, while not so readily manifest, are nevertheless of great importance. If we examine these slates in thin sections under the microscope, we find that in nearly every case the individual particles of quartz, feldspar, clayey matter, etc., of which they are made up, are more or less elongated, and arranged with their longer axes parallel with the plane of cleavage. In fact, it is this parallel arrangement of the particles that permits the separation of the slate into thin sheets with smooth surfaces. This arrangement of the constituent particles we have reason for believing was brought about by the shearing forces above alluded to. But this is not all. Pressure generates heat, and all rocks lying in the ground contain more or less moisture. It is not surprising therefore, that other changes than those of structure have been produced, particularly in the older slates, and those where dynamic agencies have been most active. In fact, a process of recrystallization is established, and new minerals formed, though it may be in sizes that are extremely minute. Not to go too much into detail, it can be said, that in short, the clay slates pass by imperceptible gradations into crystalline

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schists, and, further, that so far as the writer's present experience goes, the more crystalline the rock is, other things being equal, the tougher, less absorptive and more durable it is. This is well exemplified in the Peach Bottom slates referred to in Prof. Merriman's paper. These are among the most highly metamorphosed of any of the fissile argillites that are used for roofing purposes. The microscope shows in them incipient crystallizations of chiastolite and other aluminous silicates, which tend to give them strength and elasticity. Unfortunately this crystallization seems to a certain extent to interfere with the fissile property, slates of this nature yielding thicker slabs and with less even surfaces. Such, while more desirable, demand, on account of their greater weight, additional strength in roofing timbers. In the few cases in which the writer has been called upon to decide as to slates for roofs of public buildings, his decision has been invariably based upon amount of crystallization as shown by the microscope, and the presence or absence of free carbonates of lime and magnesia, sulphides of iron, or of carbonaceous matter. The "acid tests" made by Prof. Merriman serve well to show the presence of the free carbonates, the slates becoming brittle because these soluble constituents were removed. The presence of iron pyrites is indicated by the sulphur in the analyses, though it is possible that a portion of it may exist in other combinations. For this reason it would seem that the table given (page 535) is a trifle misleading, a portion of the iron there tabulated as a silicate probably existing as a sulphide.

In conclusion the writer says that he regards these tests as of very great importance, and congratulates Prof. Merriman on having discovered so simple a test as that of impact with a wooden ball, which apparently promises so much.

F. Lynwood Garrison, Assoc. M. Am. Soc. C. E., notices but one point to criticise in Prof. Merriman's excellent paper, and that is in regard to his corrosion tests. They seem to be unduly severe, and hardly to give a fair indication of the practical durability of roofing slate under ordinary circumstances. Although the atmosphere of large cities contains very small but variable quantities of certain gases, such as carbonic acid, sulphuric anhydride and some free chlorine, their corrosive action upon slate roofs, even under the most favorable circumstances, is, in the writer's judgment, extremely slight. The action of frost in breaking up and disintegrating the laminæ of the slate must be much more destructive in this irregular and variable climate. It would seem, therefore, that a freezing test would have much practical value, although such experiments are by no means easy or convenient to make. The practice of an impact test by means of dropping a ball from a fixed height upon the slate seems a good idea, possessing the advantage of being easily and quickly applied. It would seem, moreover, that such a simple test would be all required, since a fair idea of

the strength, toughness and capacity to resist shock are about the only essential factors to be determined in selecting a slate for ordinary roofing purposes.

E. H. S. BAILEY, Esq., writes that some months ago Prof. Merriman asked him in reference to the analyses of the samples of slate that he made in Lehigh University several years ago. He does not think that he published the analyses, except in a popular article. He has looked them up and gives them herewith :

	Index of Porosity.	Sulphur.	CO_2	$CaCO_3$.	Specific Gravity.
Chapman's, Pa.....	0.14	.88	3.40	7.73	2.79
Chapman's Mixed.....	0.11	.98	2.83	6.43	2.79
Red Vermont	0.21	.075	5.42	12.32	2.81
Daniels' Quarry.....	0.14	1.29	2.72	6.18	2.78
Belfast Quarry.....	0.25	1.52	2.82	6.41	2.80

In these analyses the porosity is determined by finding how much water the slate will absorb in a given time. The sulphur represents all the sulphur, both that as sulphides and as sulphates ; the calcium carbonate is calculated from the carbonic anhydride, and the specific gravity is determined with considerable care on a specimen several grams in weight. In the expression, "Chapman's Mixed," a sample made up of specimens from different parts of the quarry is referred to so as to represent the whole fairly. The "Chapman" was simply one average sample.

The amount of calcium carbonate stated in the paper is smaller than the writer reported. In his results the calcium carbonate was calculated from the carbonic acid, which was determined.

MANSFIELD MERRIMAN, M. Am. Soc. C. E., in closing the discussion, says that he agrees with Mr. Merrill as to the great value of microscopic examinations of slates and stones. Chemical analyses usually give little information as to the actual lithological composition of rocks, and it is apparent that the manner in which any element, such as sulphur, for example, exists in combination, is fully as important as the figures indicating the percentage of that element. If chemists would endeavor to give their results in such a form that the mineralogical character of the stone can be fairly inferred, instead of noting merely the substances actually determined in the analysis, their reports would be far more valuable.

With respect to the impact test it may be added that the slates were placed in a vertical plane, while the wooden ball was swung as a pendulum, its point of suspension being about 6 ft. above the specimen. The work done in one blow of the ball was its weight multiplied by the height of the vertical fall, which in each case was 9 ins.

Mr. Garrison refers to the acid tests as unduly severe. This is true, but it was the intention to make them so, in order, if possible, to obtain a better idea of the relation between resilience and corrodibility. A practical acid test, such as used for the main series on the Peach Bottom specimens, need be only from 48 to 60 hours with a solution of the strength stated. A freezing test would undoubtedly, as Mr. Garrison suggests, be an excellent one, particularly if it could be applied to slates fastened down somewhat after the manner they usually are upon roofs.

The large amount of carbonate of lime given by Professor Bailey for the red Vermont slates seems surprising in view of their well-known capacity to resist weathering. This is another illustration of how little a chemical analysis really tells regarding the physical qualities of slate. The best test of all, to compare several kinds of slate, is, of course, to put them on a roof in a manufacturing town, and then to examine them every five years until a satisfactory conclusion is reached. This in general being impracticable, it seems that the next best method is to investigate their physical properties by means of tests of strength, resilience and corrodibility, assisted if possible by microscopic examinations.